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Bergman et al.

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[54] INHIBITORS OF FARNESYL-PROTEIN TRANSFERASE

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[52] U.S. Cl. 514/357; 514/399; 546/333; 546/338; 548/375.1

[58] Field of Search 546/333, 338; 548/375.1; 514/357, 399

[56] References Cited

U.S. PATENT DOCUMENTS

5,576,313 11/1996 Fisher et al. 514/211
5,631,280 5/1997 Ciccarone et al. 514/416

FOREIGN PATENT DOCUMENTS

WO 96/30343 10/1996 WIPO .
WO 96/37204 11/1996 WIPO .

OTHER PUBLICATIONS

Exp. Opin. Ther. Patents, vol. 5(12), pp. 1269–1271 (1995), by S. L. Graham.

Exp. Opin. Ther. Patents, vol. 6(12) (1996), pp. 1295–1304, by S. L. Graham, et al.

J. of Biol. Chem., vol. 268, No. 11, pp. 7617–7620 (1993), by J. B. Gibbs, et al.

J. of Biol. Chem., vol. 269, No. 44, pp. 27706–27714 (1994), by G. L. James, et al.

J. of Biol. Chem., vol. 270, No. 11, pp. 6221–6226 (1995), by G. L. James, et al.

Science, vol. 260, pp. 1934–1937 (1993), by N. E. Kohl, et al.

Proc. Natl. Acad. Sci. USA, vol. 91, pp. 9141–9145 (1994), by N. E. Kohl, et al.

Nature Medicine, vol. 1, No. 8, pp. 792–797 (1995), by N. E. Kohl, et al.

Cancer Research, vol. 55, pp. 5302–5309 (1995), by L. Sepp-Lorenzino, et al.

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[57] ABSTRACT

The present invention is directed to compounds which inhibit farnesyl-protein transferase (FTase) and the farnesylation of the oncogene protein Ras. The invention is further directed to chemotherapeutic compositions containing the compounds of this invention and methods for inhibiting farnesyl-protein transferase and the farnesylation of the oncogene protein Ras.

31 Claims, No Drawings

INHIBITORS OF FARNESYL-PROTEIN TRANSFERASE

This application is based on Provisional Application No. 60/014,668 filed Apr. 3, 1996.

BACKGROUND OF THE INVENTION

The present invention relates to compounds which inhibit farnesyl protein transferase, a protein which is implicated in the oncogenic pathway mediated by Ras. The Ras proteins (Ha-Ras, Ki4a-Ras, Ki4b-Ras and N-Ras) are part of a signalling pathway that links cell surface growth factor receptors to nuclear signals initiating cellular proliferation. Biological and biochemical studies of Ras action indicate that Ras functions like a G-regulatory protein. In the inactive state, Ras is bound to GDP. Upon growth factor receptor activation Ras is induced to exchange GDP for GTP and undergoes a conformational change. The GTP-bound form of Ras propagates the growth stimulatory signal until the signal is terminated by the intrinsic GTPase activity of Ras, which returns the protein to its inactive GDP bound form (D. R. Lowy and D. M. Willumsen, *Ann. Rev. Biochem.* 62:851-891 (1993)). Mutated ras genes (Ha-ras, Ki4a-ras, Ki4b-ras and N-ras) are found in many human cancers, including colorectal carcinoma, exocrine pancreatic carcinoma, and myeloid leukemias. The protein products of these genes are defective in their GTPase activity and constitutively transmit a growth stimulatory signal.

Ras must be localized to the plasma membrane for both normal and oncogenic functions. At least 3 post-translational modifications are involved with Ras membrane localization, and all 3 modifications occur at the C-terminus of Ras. The Ras C-terminus contains a sequence motif termed a "CAAX" or "Cys-Aaa¹-Aaa²-Xaa" box (Cys is cysteine, Aaa is an aliphatic amino acid, the Xaa is any amino acid) (Willumsen et al., *Nature* 310:583-586 (1984)). Depending on the specific sequence, this motif serves as a signal sequence for the enzymes farnesyl-protein transferase or geranylgeranyl-protein transferase, which catalyze the alkylation of the cysteine residue of the CAAX motif with a C₁₅ or C₂₀ isoprenoid, respectively. (S. Clarke, *Ann. Rev. Biochem.* 61:355-386 (1992); W. R. Schafer and J. Rine, *Ann. Rev. Genetics* 30:209-237 (1992)). Ras proteins are known to undergo post-translational farnesylation. Other farnesylated proteins include the Ras-related GTP-binding proteins such as Rho, fungal mating factors, the nuclear lamins, and the gamma subunit of transducin. James, et al., *J. Biol. Chem.* 269, 14182 (1994) have identified a peroxisome associated protein Pxf which is also farnesylated. James, et al., have also suggested that there are farnesylated proteins of unknown structure and function in addition to those listed above.

Inhibition of farnesyl-protein transferase has been shown to block the growth of Ras-transformed cells in soft agar and to modify other aspects of their transformed phenotype. It has also been demonstrated that certain inhibitors of farnesyl-protein transferase selectively block the processing of the Ras oncoprotein intracellularly (N. E. Kohl et al., *Science*, 260:1934-1937 (1993) and G. L. James et al., *Science*, 260:1937-1942 (1993)). Recently, it has been shown that an inhibitor of farnesyl-protein transferase blocks the growth of ras-dependent tumors in nude mice (N. E. Kohl et al., *Proc. Natl. Acad. Sci. U.S.A.*, 91:9141-9145 (1994) and induces regression of mammary and salivary carcinomas in ras transgenic mice (N. E. Kohl et al., *Nature Medicine*, 1:792-797 (1995)).

Indirect inhibition of farnesyl-protein transferase *in vivo* has been demonstrated with lovastatin (Merck & Co., Rahway, N.J.) and compactin (Hancock et al., *ibid*; Casey et al., *ibid*; Schafer et al., *Science* 245:379 (1989)). These drugs inhibit HMG-CoA reductase, the rate limiting enzyme for the production of polyisoprenoids including farnesyl pyrophosphate. Farnesyl-protein transferase utilizes farnesyl pyrophosphate to covalently modify the Cys thiol group of the Ras CAAX box with a farnesyl group (Reiss et al., *Cell*, 62:81-88 (1990); Schaber et al., *J. Biol. Chem.*, 265:14701-14704 (1990); Schafer et al., *Science*, 249:1133-1139 (1990); Manne et al., *Proc. Natl. Acad. Sci. USA*, 87:7541-7545 (1990)). Inhibition of farnesyl pyrophosphate biosynthesis by inhibiting HMG-CoA reductase blocks Ras membrane localization in cultured cells. However, direct inhibition of farnesyl-protein transferase would be more specific, and thus preferable.

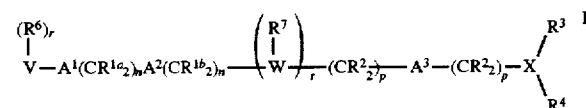
Inhibitors of farnesyl-protein transferase (FPTase) have been described in two general classes. The first are analogs of farnesyl diphosphate (FPP), while the second class of inhibitors is related to the protein substrates (e.g., Ras) for the enzyme. The peptide derived inhibitors that have been described are generally cysteine containing molecules that are related to the CAAX motif that is the signal for protein prenylation. (Schaber et al., *ibid*; Reiss et al., *ibid*; Reiss et al., *PNAS*, 88:732-736 (1991)). Such inhibitors may inhibit protein prenylation while serving as alternate substrates for the farnesyl-protein transferase enzyme, or may be purely competitive inhibitors (U.S. Pat. No. 5,141,851, University of Texas; N. E. Kohl et al., *Science*, 260:1934-1937 (1993); Graham, et al., *J. Med. Chem.*, 37, 725 (1994)).

It has recently been reported that FPTase inhibitors also inhibit the proliferation of vascular smooth muscle cells and are therefore useful in the prevention and treatment of arteriosclerosis and diabetic disturbance of blood vessels (JP H7-112930).

It has recently been disclosed that certain tricyclic compounds which optionally incorporate a piperidine moiety are inhibitors of FPTase (WO 95/10514, WO 95/10515 and WO 95/10516). Imidazole-containing inhibitors of farnesyl protein transferase have also been disclosed (WO 95/09001 and EP 0 675 112 A1).

SUMMARY OF THE INVENTION

The present invention addresses a compound of formula I:



or a pharmaceutically acceptable salt thereof, wherein:

R^{1a}, R^{1b} and R² are independently selected from the group consisting of: hydrogen, aryl, heterocyclyl, C₃-C₁₀ cycloalkyl, C₂-C₆ alkenyl, C₂-C₆ alkynyl, R⁸O-, R⁹S(O)_m-, (R⁸)₂NC(O)-, R⁸C(O)NR⁸-, CN, NO₂, (R⁸)₂NC(NR⁸)-, R⁸C(O)-, R⁸OC(O)-, N₃-, -N(R⁸)₂, R⁹OC(O)NR⁸- and C₁-C₆ alkyl, unsubstituted or substituted by 1-3 groups selected from the group consisting of: halo, aryl, heterocyclyl, C₃-C₁₀ cycloalkyl, C₂-C₆ alkenyl, C₂-C₆ alkynyl, R⁸O-, R⁹S(O)_m-, R⁸C(O)NR⁸-, CN, (R⁸)₂NC(NR⁸)-, R⁸C(O)-, R⁸OC(O)-, N₃-, -N(R⁸)₂ and R⁹OC(O)NR⁸-;

R³ and R⁴ are independently selected from the group consisting of: H, F, Cl, Br, -NR⁸, CF₃, NO₂, R⁸O-, R⁹S(O)_m-, (R⁸)₂NC(O)-, R⁸C(O)NH-, H₂NC(NH)-,

$R^8C(O)-$, $R^8OC(O)-$, N_3 , CN , $R^9OC(O)NR^8-$, C_1-C_{20} alkyl, substituted or unsubstituted aryl and substituted or unsubstituted heterocyclyl;

A^3 is selected from: $-NR^5S(O)_m-$ or $-S(O)_mNR^5-$, with m equal to 0, 1 or 2, and R^5 selected from the group consisting of: hydrogen, unsubstituted or substituted aryl, unsubstituted or substituted heterocyclyl, unsubstituted or substituted C_3-C_{10} cycloalkyl, and C_1-C_6 alkyl, unsubstituted or substituted with 1-3 members selected from the group consisting of: unsubstituted or substituted aryl, unsubstituted or substituted heterocyclyl, unsubstituted or substituted C_3-C_{10} cycloalkyl, $-N(R^8)_2$, $-CF_3$, $-NO_2$, $(R^8)O-$, $(R^9)S(O)_m-$, $(R^8)C(O)NH-$, $H_2NC(NH)-$, $(R^8)C(O)-$, $(R^8)OC(O)-$, N_3 , CN and $(R^9)OC(O)NR^8-$;

R^6 and R^7 are independently selected from the group consisting of: hydrogen, aryl, heterocyclyl, C_3-C_{10} cycloalkyl, C_2-C_6 alkenyl, C_2-C_6 alkynyl, C_1-6 perfluoroalkyl, F , Cl , Br , R^8O- , $R^9S(O)_m-$, $R^8C(O)NR^8-$, CN , NO_2 , $(R^8)_2NC(NR^8)-$, $R^8C(O)-$, $R^8OC(O)-$, N_3 , $-N(R^8)_2$, $R^9OC(O)NR^8-$ and C_1-C_6 alkyl unsubstituted or substituted by 1-3 groups selected from: aryl, heterocyclyl, C_3-C_{10} cycloalkyl, C_2-C_6 alkenyl, C_2-C_6 alkynyl, perfluoroalkyl, F , Cl , Br , R^8O- , $R^9S(O)_m-$, $R^8C(O)NR^8-$, CN , $(R^8)_2NC(NR^8)-$, $R^8C(O)-$, $R^8OC(O)-$, N_3 , $-N(R^8)_2$ and $R^9OC(O)NR^8-$;

each R^8 is independently selected from hydrogen, C_1-C_6 alkyl, aryl and aralkyl;

each R^9 is independently selected from C_1-C_6 alkyl and aryl;

A^1 and A^2 are independently selected from the group consisting of: a bond, $-CH=CH-$, $-C\equiv C-$, $-C(O)-$, $-C(O)NR^8-$, $-NR^8C(O)-$, $-O-$, $-N(R^8)-$, $-S(O)_2N(R^8)-$, $-N(R^8)S(O)_2-$, and $S(O)_m$;

X represents aryl or heteroaryl;

V is selected from the group consisting of: hydrogen, heterocyclyl, aryl, C_1-C_{20} alkyl wherein from 0 to 4 carbon atoms are replaced with a heteroatom selected from O , S , and N , and C_2-C_{20} alkenyl, provided that V is not hydrogen if A^1 is $S(O)_m$ and V is not hydrogen if A^1 is a bond, n is 0 and A^2 is $S(O)_m$;

W represents heterocyclyl;

each n and p independently represents 0, 1, 2, 3 or 4;

r is 0 to 5, provided that r is 0 when V is hydrogen, and t is 0 or 1.

DETAILED DESCRIPTION OF THE INVENTION

The compounds of this invention are useful in the inhibition of farnesyl-protein transferase and the farnesylation of the oncogene protein Ras, and thus are useful for the treatment of cancer.

The compounds of the present invention may have asymmetric centers and occur as racemates, racemic mixtures and as individual diastereomers, with all possible isomers, including optical isomers, being included in the present invention.

When any variable (e.g. aryl, heterocycle, R^1 , R^2 etc.) occurs more than one time in any constituent, each definition is independent.

The term "alkyl" and the alkyl portion of alkoxy, aralkyl and similar terms, is intended to include branched and straight-chain saturated aliphatic hydrocarbon groups having the specified number of carbon atoms, or 1-6 carbon atoms if unspecified. Cycloalkyl means 1-2 cabocyclic rings which are saturated and contain from 3-10 atoms.

"Halogen" or "halo" as used herein means fluoro, chloro, bromo and iodo.

As used herein, "aryl" and the aryl portion of aralkyl, are intended to mean any stable monocyclic or bicyclic carbon ring of up to 7 members in each ring, wherein at least one ring is aromatic. Examples of such aryl elements include phenyl, naphthyl, tetrahydronaphthyl, indanyl, biphenyl, phenanthryl, anthryl or acenaphthyl. A preferred aralkyl group is benzyl.

The terms heterocyclyl, heterocycle and heterocyclic, as used herein, mean a 5- to 7-membered monocyclic or 8- to 11-membered bicyclic heterocyclic rings, either saturated or unsaturated, aromatic, partially aromatic or non-aromatic, and which consist of carbon atoms and from one to four heteroatoms selected from the group consisting of N , O , and S . Thus, it includes any bicyclic group in which any of the above-defined heterocyclic rings is fused to a benzene ring. The ring or ring system may be attached at any heteroatom or carbon atom which results in a stable structure, and may contain 1-3 carbonyl groups. Examples of such heterocycles include, but are not limited to, azepinyl, benzimidazolyl, benzisoxazolyl, benzofurazanyl, benzopyranyl, benzothiopyranyl, benzofuryl, benzothiazolyl, benzothienyl, benzoxazolyl, chromanyl, cinnolyl, dihydrobenzofuryl, dihydrobenzothienyl, dihydrobenzothiopyranyl, dihydrobenzothiopyranyl sulfone, furyl, imidazolidinyl, imidazolyl, indolyl, indolyl, isochromanyl, isoindolyl, isoquinolyl, isothiazolidinyl, isothiazolyl, isothiazolidinyl, morpholyl, naphthyridinyl, oxadiazolyl, 2-oxoazepinyl, oxazolyl, 2-oxopiperazinyl, 2-oxopiperdinyl, 2-oxopyrrolidinyl, piperidyl, piperazinyl, pyridyl, pyrazinyl, pyrazolidinyl, pyrazolyl, pyridazinyl, pyrimidinyl, pyrrolidinyl, pyrrolyl, quinazolyl, quinolyl, quinoxalyl, tetrahydrofuryl, tetrahydroisoquinolyl, tetrahydroquinolyl, thiamorpholyl, thiamorpholyl sulfoxide, thiazolyl, thiazolyl, thienofuryl, thienothienyl, and thienyl.

"Heteroaryl" is a subset of heterocyclic, and means a monocyclic or bicyclic ring system, with up to 7 members in each ring, wherein at least one ring is aromatic and wherein from one to four carbon atoms are replaced by heteroatoms selected from the group consisting of N , O , and S . Examples include benzimidazolyl, benzisoxazolyl, benzofurazanyl, benzopyranyl, benzothiopyranyl, benzofuryl, benzothiazolyl, benzothienyl, benzoxazolyl, chromanyl, cinnolyl, dihydrobenzofuryl, dihydrobenzothienyl, dihydrobenzothiopyranyl, dihydrobenzothiopyranyl sulfone, furyl, imidazolyl, indolyl, indolyl, isochromanyl, isoindolyl, isoquinolyl, isothiazolyl, naphthyridinyl, oxadiazolyl, pyridyl, pyrazinyl, pyrazolyl, pyridazinyl, pyrimidinyl, pyrrolyl, quinazolyl, quinolyl, quinoxalyl, tetrahydroisoquinolyl, tetrahydroquinolyl, thiazolyl, thienofuryl, thienothienyl and thienyl.

Lines drawn into ring systems from substituents indicate that the bond may be attached to any of the substitutable ring atoms.

The term "substituted" as used with respect to, e.g., substituted alkyl, substituted aryl, substituted heterocyclyl and substituted cycloalkyl mean alkyl, aryl, heterocyclyl and cycloalkyl groups, respectively, having from 1-3 substituents which are selected from: halo, aryl, heterocyclyl, C_3-10 cycloalkyl, C_1-6 alkyl, C_2-6 alkenyl, C_2-6 alkynyl, R^8O- , $R^9S(O)_m-$, $R^8C(O)NR^8-$, CN , $(R^8)_2NC(NR^8)-$, $R^8C(O)-$, $R^8OC(O)-$, N_3 , $-N(R^8)_2$ and $R^9OC(O)NR^8-$.

Preferably 1-2 groups are present on substituted alkyl, substituted aryl, substituted heterocyclyl and substituted cycloalkyl, which are selected from: halo, aryl, R^8O- , CN , $R^8C(O)-$ and $-N(R^8)_2$.

5

Preferably, R^{1a} , R^{1b} and R^2 are independently selected from: hydrogen, $-N(R^8)_2$, $R^8C(O)NR^8-$ or unsubstituted or substituted C_1-C_6 alkyl wherein the substituent on the substituted C_1-C_6 alkyl is selected from unsubstituted or substituted aryl, $-N(R^8)_2$, R^8O- and $R^8C(O)NR^8-$. Preferably, R^3 and R^4 are selected from: hydrogen and C_1-C_6 alkyl.

Preferably, A^3 represents $NR^5S(O)_m$, wherein m represents 2 and R^5 represents hydrogen.

Preferably, R^6 represents hydrogen, unsubstituted or substituted C_1-C_6 alkyl.

Preferably R^7 represents H or unsubstituted C_{1-6} alkyl.

Preferably, R^8 represents H or C_{1-6} alkyl, and R^9 is C_{1-6} alkyl.

Preferably, A^1 and A^2 are independently selected from: a bond, $-C(O)NR^8-$, $-NR^8C(O)-$, $-O-$, $-N(R^8)-$, $-S(O)_2N(R^8)-$ and $-N(R^8)S(O)_2-$.

Preferably X represents aryl and most preferably phenyl.

Preferably, V is selected from hydrogen, heterocyclyl and aryl. More preferably V is phenyl.

Preferably, W is heterocyclyl selected from imidazolyl, imidazolyl, oxazolyl, pyrazolyl, pyrrolidinyl, thiazolyl and pyridyl. More preferably, W is selected from imidazolyl and pyridyl.

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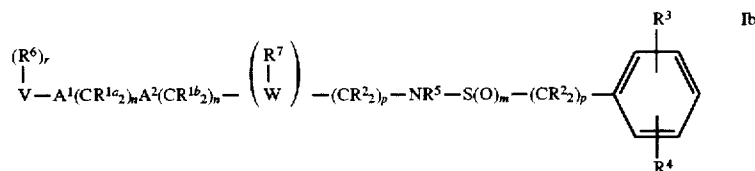
$R^8C(O)NR^8-$, CN , NO_2 , $(R^8)_2N-C(NR^8)-$, $R^8C(O)-$, $R^8OC(O)-$, $-N(R^8)_2$, or $R^9OC(O)NR^8-$, and C_1-C_6 alkyl substituted by C_1-C_6 perfluoroalkyl, R^8O- , $R^8C(O)NR^8-$, $(R^8)_2N-C(NR^8)-$, $R^8C(O)-$, $R^8OC(O)-$, $-N(R^8)_2$ and $R^9OC(O)NR^8-$;

R^7 is hydrogen or unsubstituted C_{1-6} alkyl;

A^1 and A^2 are independently selected from: a bond, $-CH=CH-$, $-C\equiv C-$, $-C(O)-$, $-C(O)NR^8-$, O , $-N(R^8)-$ and $S(O)_m$;

and V is selected from: hydrogen; aryl; heterocyclyl selected from pyrrolidinyl, imidazolyl, pyridinyl, thiazolyl, pyridonyl, 2-oxopiperidinyl, indolyl, quinolinyl, isoquinolinyl and thienyl; C_1-C_{20} alkyl wherein from 0 to 4 carbon atoms are replaced with a heteroatom selected from O, S, and N, and C_2-C_{20} alkenyl, provided that V is not hydrogen if A^1 is $S(O)_m$ and V is not hydrogen if A^1 is a bond and A^2 is $S(O)_m$.

A second subset of compounds of the present invention is represented by formula Ib:

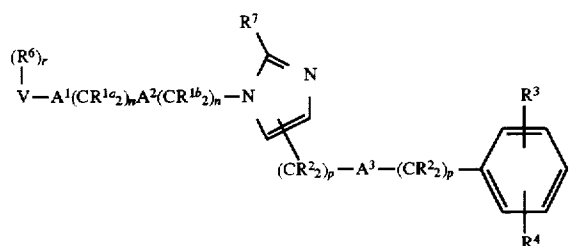


Preferably, m is 2.

Preferably n and p are independently 0, 1, 2 or 3.

Preferably t is 1.

A subset of compounds of the invention is represented by formula Ia:



wherein:

R^3 , R^4 , A^3 , R^8 , R^9 , m , n , p and r are as originally defined; each R^{1a} and R^2 is independently selected from hydrogen and C_1-C_6 alkyl;

each R^{1b} is independently selected from: hydrogen, aryl, heterocyclyl, C_{3-10} cycloalkyl, C_{2-6} alkenyl, R^8O- , $-N(R^8)_2$ and C_1-C_6 alkyl unsubstituted or substituted by aryl, heterocyclyl, cycloalkyl, alkenyl, R^8O- and $-N(R^8)_2$;

R^5 is selected from the group consisting of: hydrogen and C_1-C_6 alkyl, unsubstituted or substituted with 1-3 members selected from the group consisting of: unsubstituted or substituted aryl, unsubstituted or substituted heterocyclyl, unsubstituted or substituted C_3-C_{10} cycloalkyl, $-N(R^8)_2$, $-CF_3$, $-NO_2$, $(R^8)O-$, $(R^8)S(O)_m-$, $(R^8)C(O)NH-$, $H_2NC(NH)-$, $(R^8)C(O)-$, $(R^8)OC(O)-$, N_3 , CN and $(R^9)OC(O)NR^8-$;

R^6 is selected from: hydrogen, C_1-C_6 alkyl, C_2-C_6 alkenyl, C_2-C_6 alkenyl, C_1-C_6 perfluoroalkyl, F, Cl, R^8O- ,

wherein:

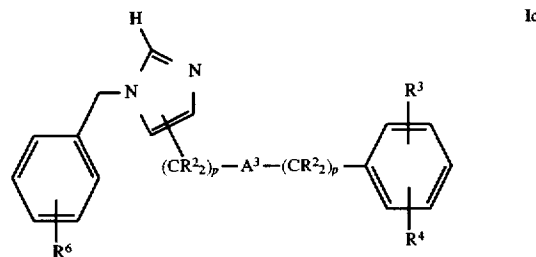
R^{1a} , R^{1b} , R^2 , A^1 , A^2 , R^3 , R^4 , R^5 , R^6 , R^8 , R^9 , m , n , p and r are as originally defined;

R^7 is selected from: hydrogen and unsubstituted C_{1-6} alkyl;

V is selected from: hydrogen, heterocyclyl selected from pyrrolidinyl, imidazolyl, pyridinyl, thiazolyl, pyridonyl, 2-oxopiperidinyl, indolyl, quinolinyl, isoquinolinyl, and thienyl, aryl, C_1-C_{20} alkyl wherein from 0 to 4 carbon atoms are replaced with a heteroatom selected from O, S, and N, and C_2-C_{20} alkenyl, provided that V is not hydrogen if A^1 is $S(O)_m$ and V is not hydrogen if A^1 is a bond, n is 0 and A^2 is $S(O)_m$; and

W represents heterocyclyl selected from pyrrolidinyl, pyridinyl, thiazolyl, pyridonyl, 2-oxopiperidinyl, indolyl, quinolinyl and isoquinolinyl.

A third embodiment of the invention is described in accordance with formula Ic:



wherein:

each R^2 is independently selected from hydrogen and C_1-C_6 alkyl;

R^3 , R^4 , A^3 , R^8 , R^9 , m and p are as originally defined;

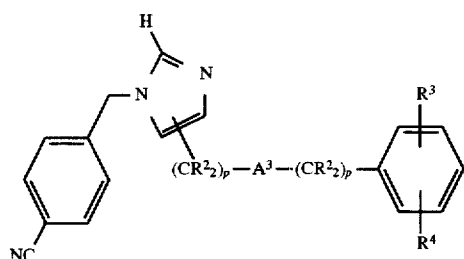
each R^5 is selected from: hydrogen and C_1-C_6 alkyl unsubstituted or substituted with 1-3 groups selected from

7

unsubstituted or substituted aryl, unsubstituted or substituted heterocyclyl, unsubstituted or substituted C₃-C₁₀ cycloalkyl, —N(R⁸)₂, —CF₃, —NO₂, (R⁸)O—, (R⁹)S(O)_m—, (R⁸)C(O)NH—, H₂NC(NH)—, (R⁸)C(O)—, (R⁸)OC(O)—, N₃, —CN and (R⁹)OC(O)NR⁸—;

and R⁶ is selected from the group consisting of: hydrogen, C₁-C₆ alkyl, C₂-C₆ alkenyl, C₂-C₆ alkynyl, C₁-C₆ perfluoroalkyl, F, Cl, R⁸O—, R⁸C(O)NR⁸—, CN, NO₂, (R⁸)₂N—C(NR⁸)—, R⁸C(O)—, R⁸OC(O)—, —N(R⁸)₂, or R⁹OC(O)NR⁸— and C₁-C₆ alkyl substituted by C₁-C₆ perfluoroalkyl, R⁸O—, R⁸C(O)NR⁸—, (R⁸)₂N—C(NR⁸)—, R⁸C(O)—, R⁸OC(O)—, —N(R⁸)₂ or R⁹OC(O)NR⁸—.

A fourth subset of compounds of the invention is represented by formula Id:



wherein:

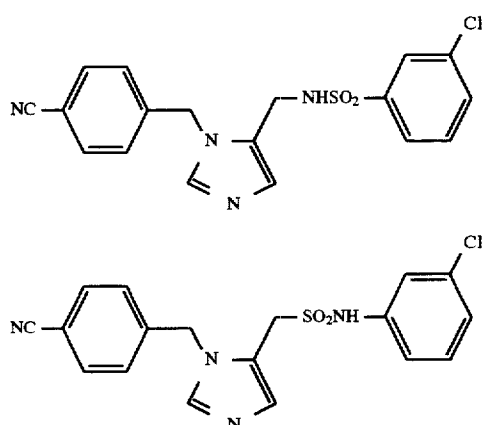
each R² is independently selected from: hydrogen and C₁-C₆ alkyl;

R³ and R⁴ are independently selected from H, F, Cl, Br, N(R⁸)₂, CF₃, NO₂, (R⁸)O—, (R⁹)S(O)_m—, (R⁸)C(O)NH—, H₂N—C(NH)—, (R⁸)C(O)—, (R⁸)OC(O)—, N₃, CN, (R⁹)OC(O)NR⁸—, C₁-C₂₀ alkyl, substituted or unsubstituted aryl, and substituted or unsubstituted heterocyclyl;

A³ represents —NR⁵—S(O)_m— or —S(O)_m—NR⁵—;

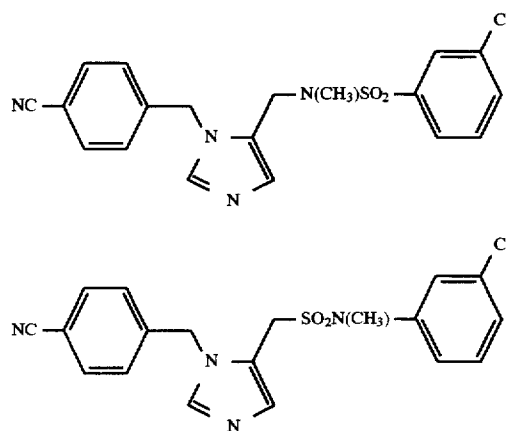
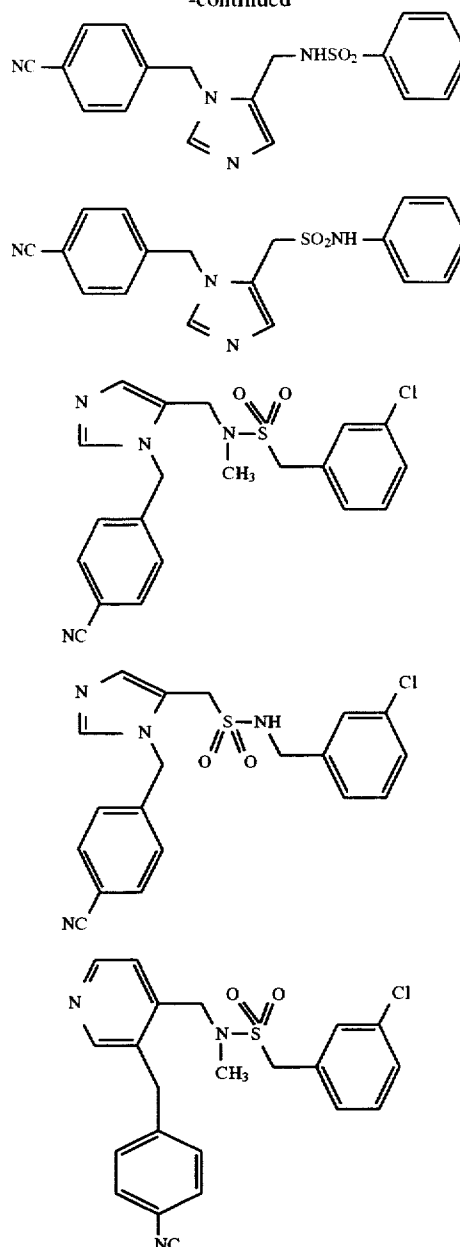
R⁵ is selected from: hydrogen and C₁-C₆ alkyl, unsubstituted or substituted with a group selected from unsubstituted or substituted aryl, unsubstituted or substituted heterocyclyl, unsubstituted or substituted C₃-C₁₀ cycloalkyl, N(R⁸)₂, CF₃, NO₂, (R⁸)O—, (R⁹)S(O)_m—, (R⁸)C(O)NH—, H₂N—C(NH)—, (R⁸)C(O)—, (R⁸)OC(O)—, N₃, CN, (R⁹)OC(O)NR⁸—; and R⁸, R⁹, m and p are as originally defined.

Specific examples of compounds of the invention are:



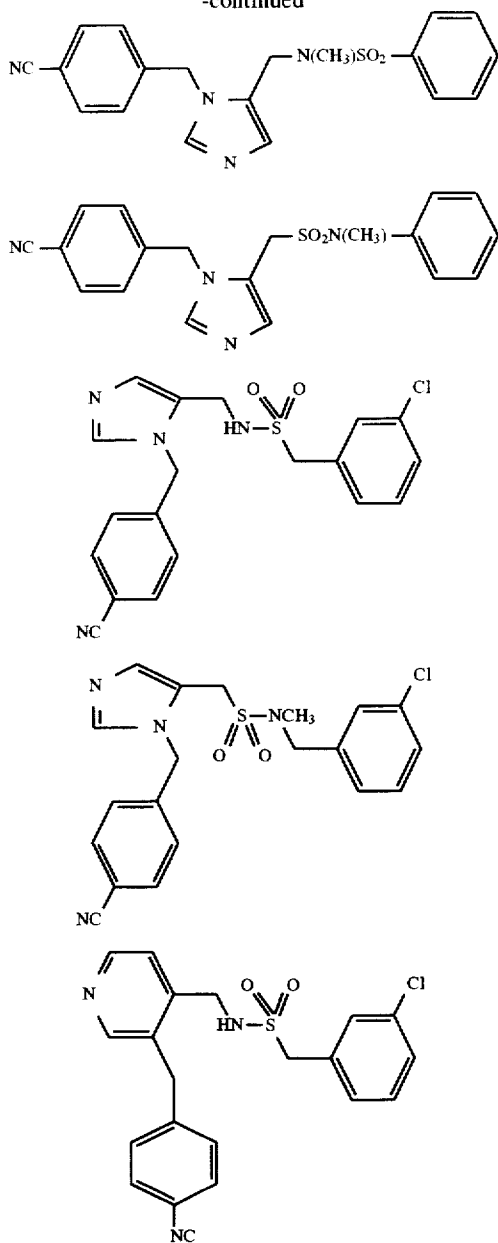
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-continued



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-continued



and the pharmaceutically acceptable salts thereof.

The pharmaceutically acceptable salts of the compounds of this invention include the conventional non-toxic salts of the compounds of this invention as formed, e.g., from non-toxic inorganic or organic acids. For example, such conventional non-toxic salts include those derived from inorganic acids such as hydrochloric, hydrobromic, sulfuric, sulfamic, phosphoric, nitric and the like; and the salts prepared from organic acids such as acetic, propionic, succinic, glycolic, stearic, lactic, malic, tartaric, citric, ascorbic, pantoic, maleic, hydroxymaleic, phenylacetic, glutamic, benzoic, salicylic, sulfanilic, 2-acetoxy-benzoic, fumaric, toluenesulfonic, methanesulfonic, ethane disulfonic, oxalic, isethionic, trifluoroacetic and the like.

The pharmaceutically acceptable salts of the compounds of this invention can be synthesized from the compounds of this invention which contain a basic moiety by conventional chemical methods. Generally, the salts are prepared either by ion exchange chromatography or by reacting the free base

10

with stoichiometric amounts or with an excess of the desired salt-forming inorganic or organic acid in a suitable solvent or various combinations of solvents.

Reactions used to generate the compounds of this invention are prepared by employing reactions as shown in Schemes 1-7, in addition to other standard manipulations such as ester hydrolysis, cleavage of protecting groups, etc., as may be known in the literature or exemplified in the experimental procedures. Substituents R' and R'CH₂—, as shown in the Schemes, represent the substituents R⁸, R⁹ and others, depending on the compound of the instant invention that is being synthesized. The variable p' represents p-1.

These reactions may be employed in a linear sequence to provide the compounds of the invention or they may be used to synthesize fragments which are subsequently joined by the alkylation reactions described in the Schemes.

Synopsis of Schemes

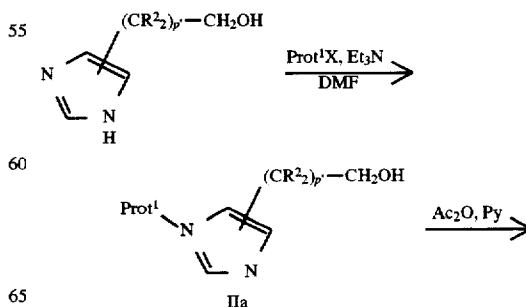
The requisite intermediates are commercially available or can be prepared according to literature procedures. The Schemes illustrate the synthesis of certain preferred embodiments of the instant invention, wherein the variable W is present as an imidazolyl moiety that is substituted. Substituted protected imidazole alkanols II can be prepared by methods, such as those described by F. Schneider, *Z. Physiol. Chem.*, 3:206-210 (1961) and C. P. Stewart, *Biochem. Journal*, 17:130-133 (1923). Benzoylation and deprotection of the imidazole alkanol provides an intermediate which can be oxidized to the corresponding aldehyde.

The aldehyde IV is reacted with a suitably substituted amine. The intermediate can then be reacted with a sulfinyl chloride.

Syntheses of suitably substituted aldehydes are illustrated wherein the variable W is present as a pyridyl moiety. Similar synthetic strategies for preparing alkanols that incorporate other heterocyclic moieties for variable W are also well known in the art.

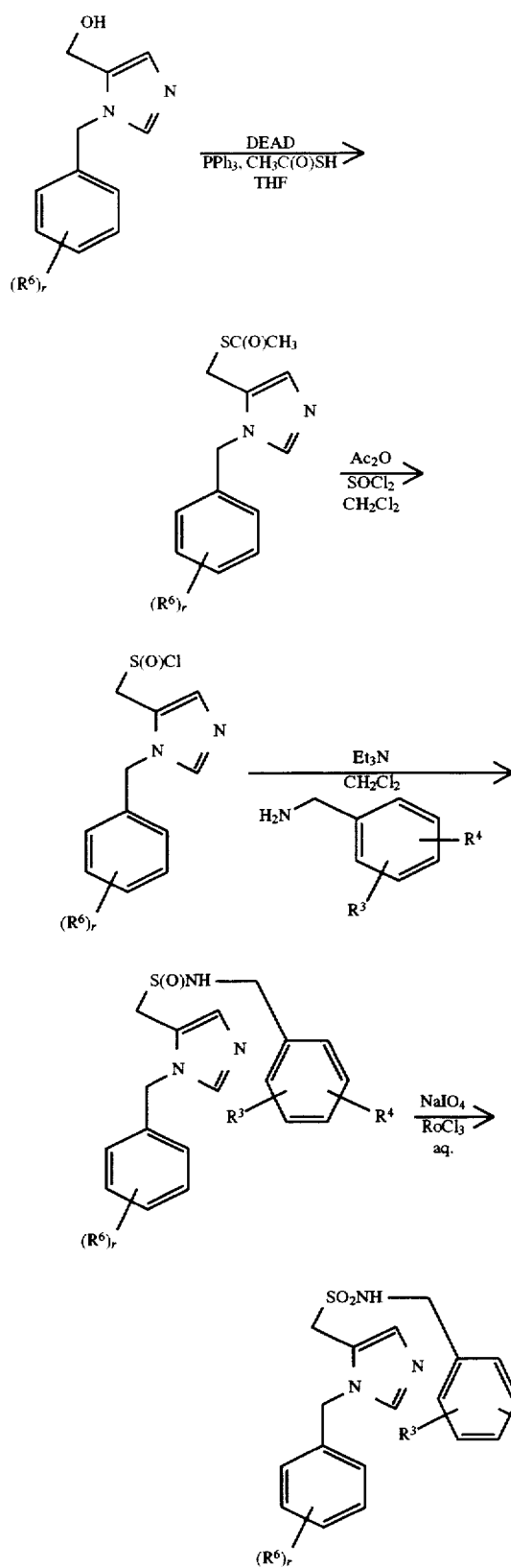
The sulfonamide can be formed by converting a hydroxyl group to a sulfinyl chloride, and then reacting the sulfinyl chloride with the appropriately substituted amine. The resulting sulfonamide can thereafter be oxidized with, e.g., periodate, to produce sulfonamides in accordance with formula I. Likewise, by reacting the precursor amine with an alkylating agent, substitution on the sulfonamide nitrogen atom can be realized.

SCHEME 1



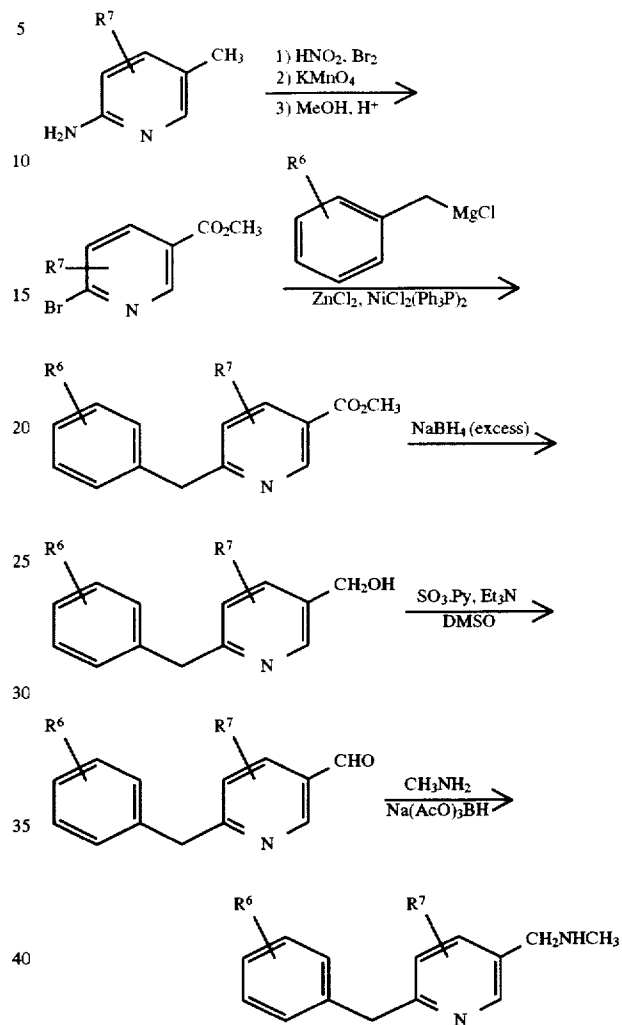
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SCHEME 4

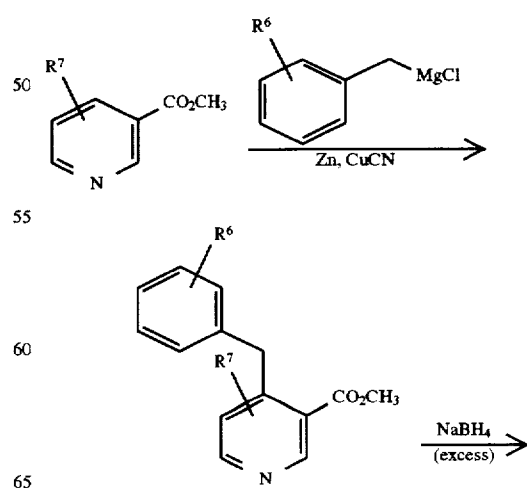


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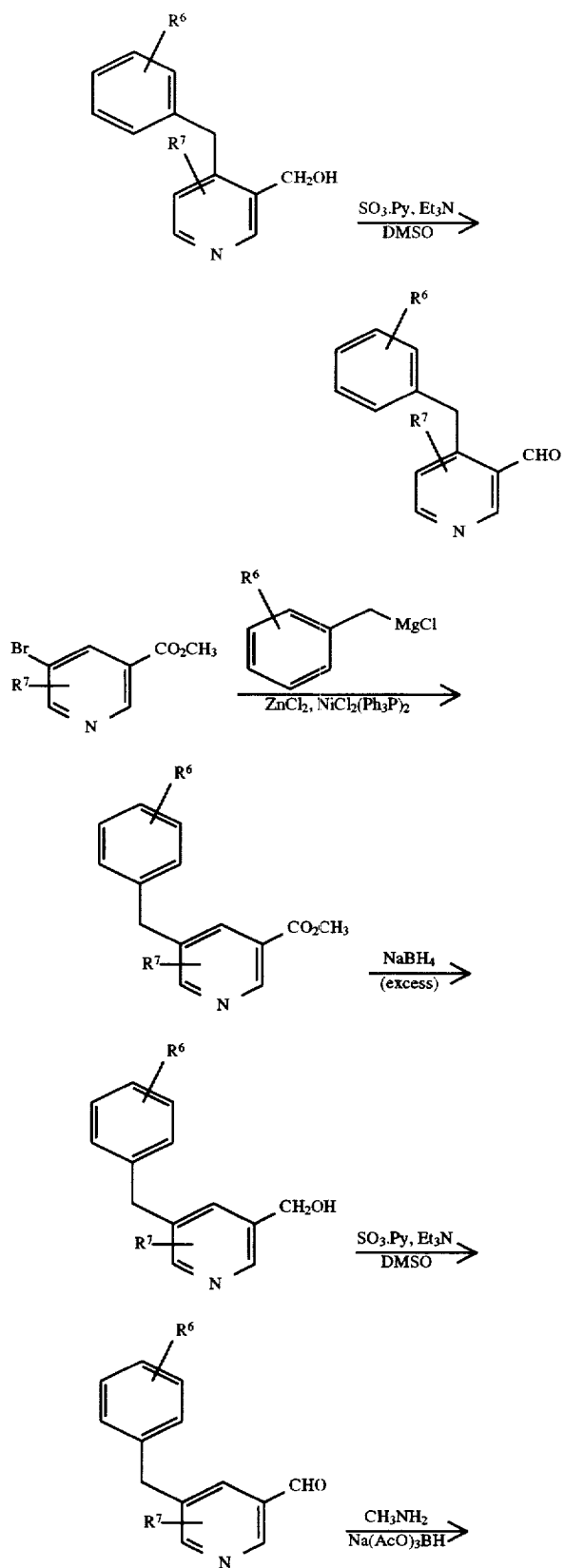
SCHEME 5



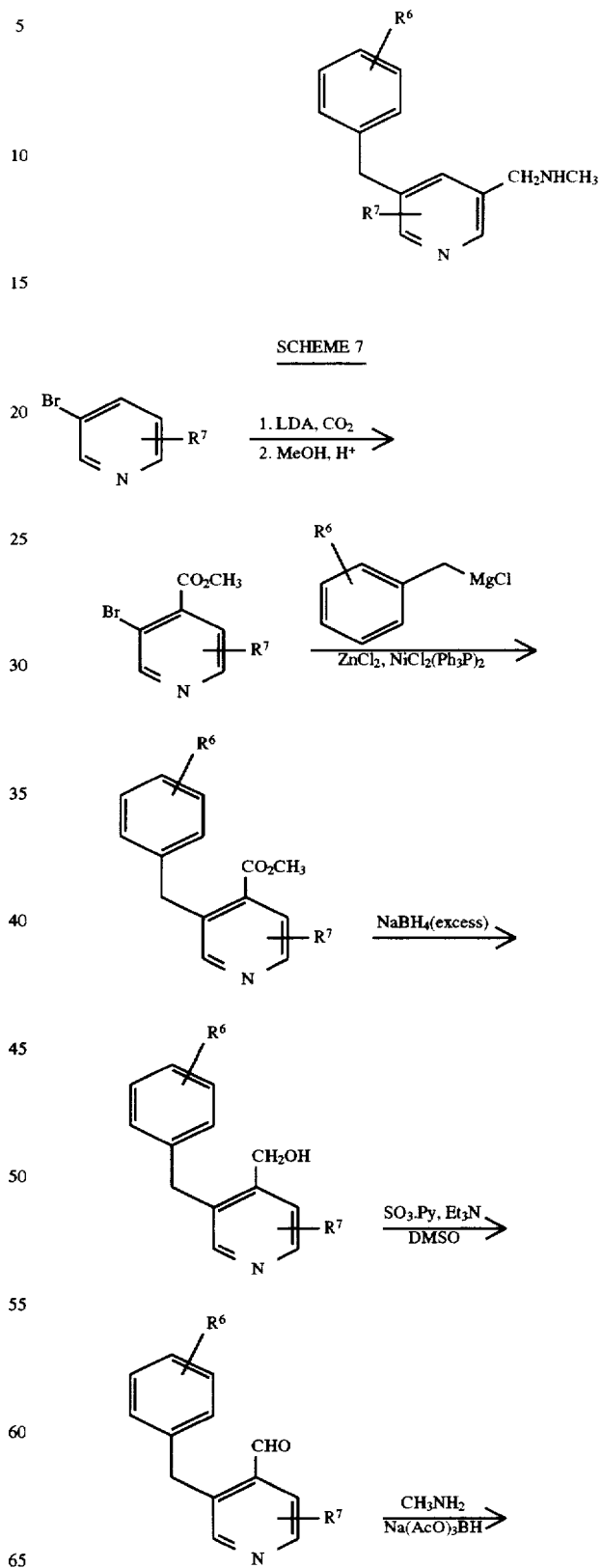
SCHEME 6



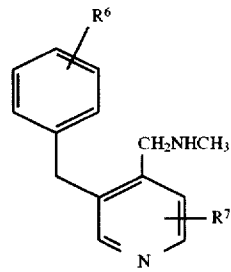
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SCHEME 6

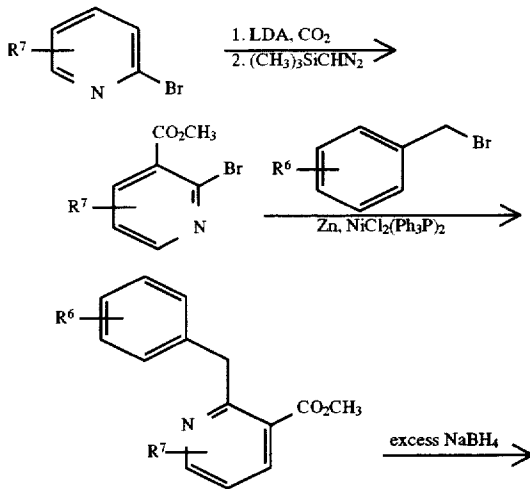
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SCHEME 6

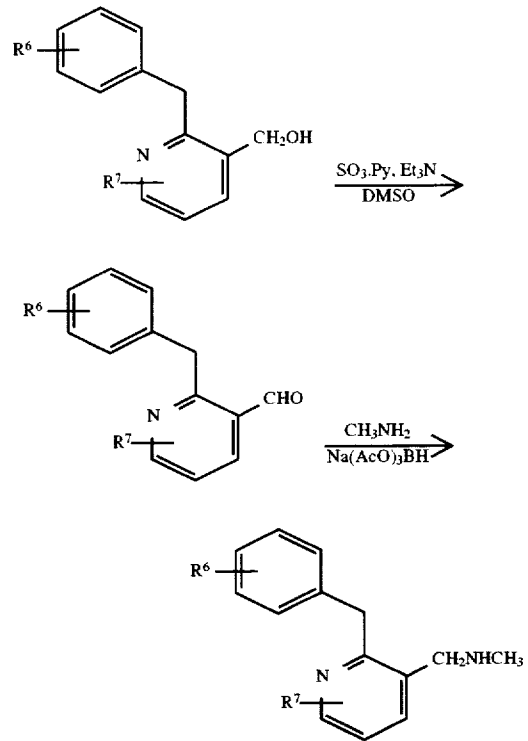
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SCHEME 7

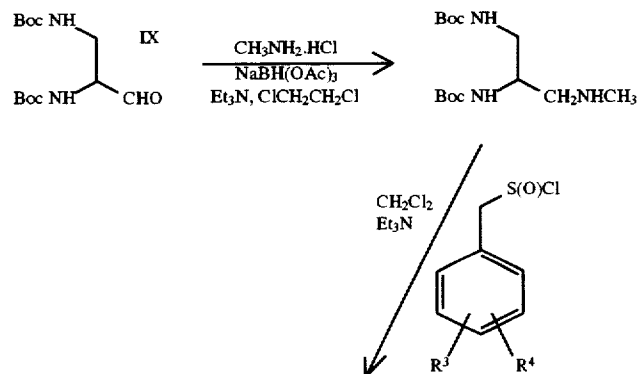
SCHEME 8



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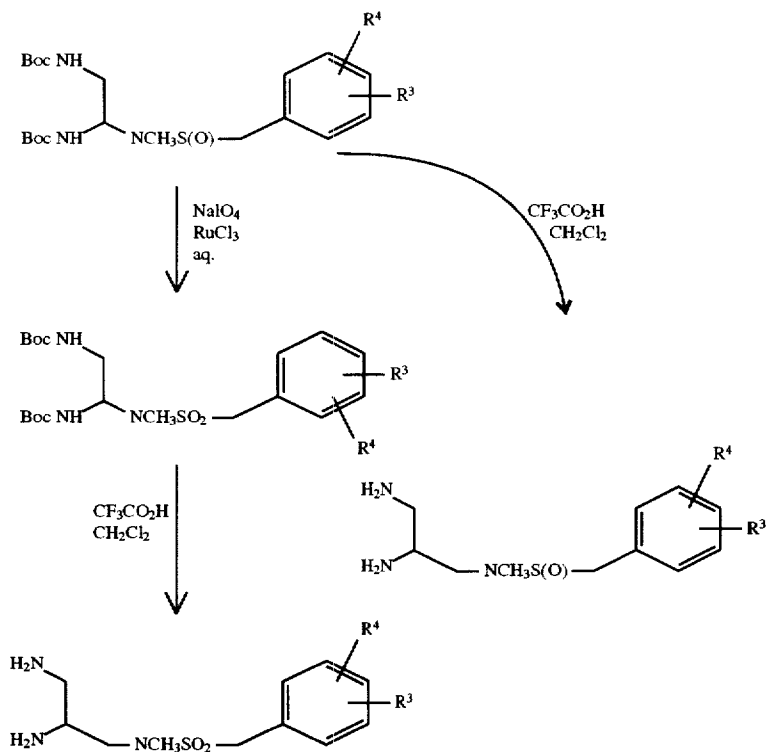
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SCHEME 8

SCHEME 9

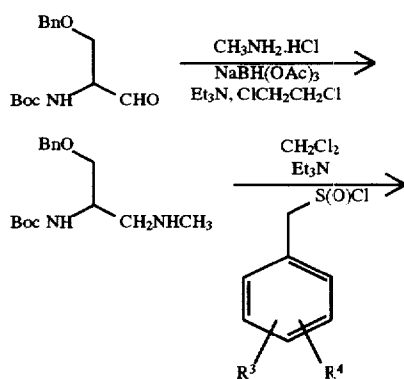


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SCHEME 9

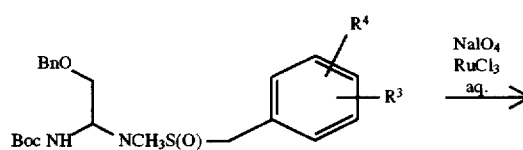
SCHEME 10

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SCHEME 10

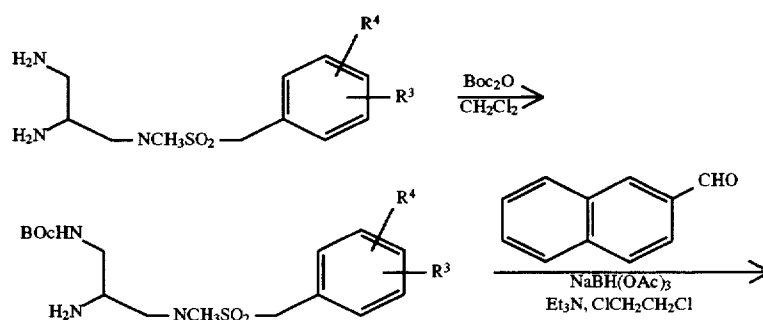
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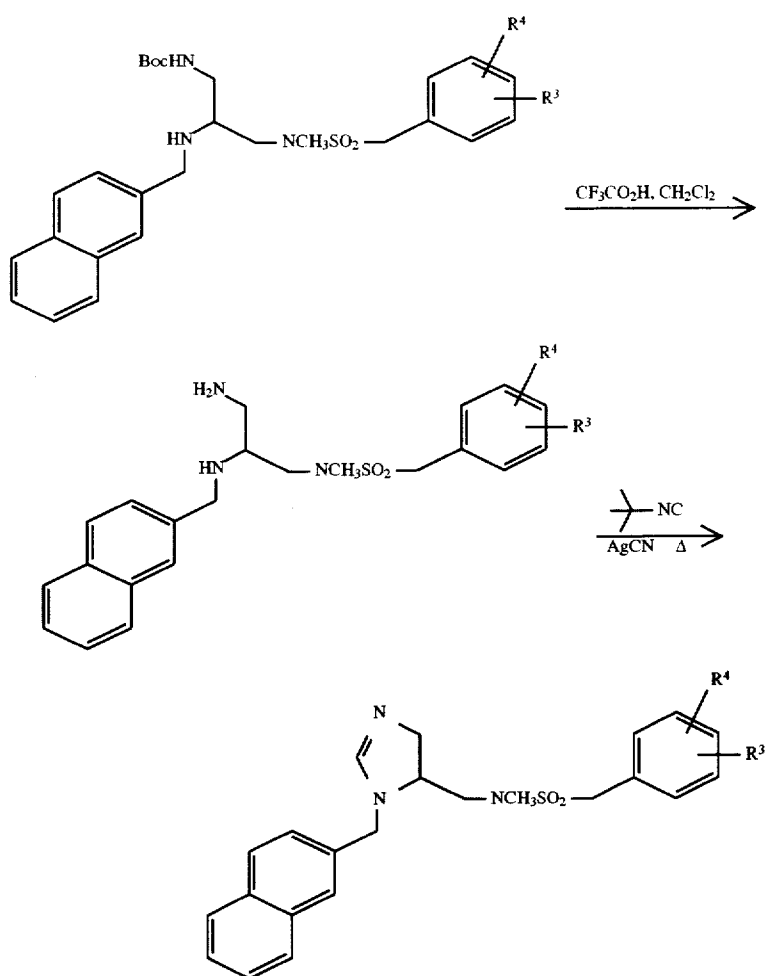
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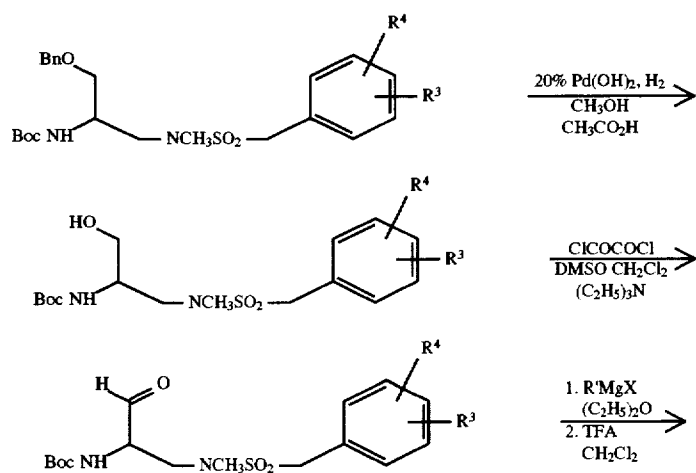
SCHEME 11



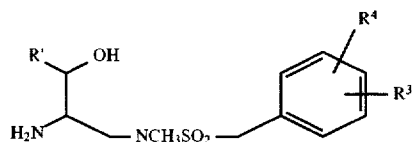
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SCHEME 11



SCHEME 12

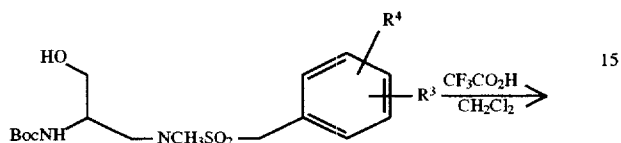


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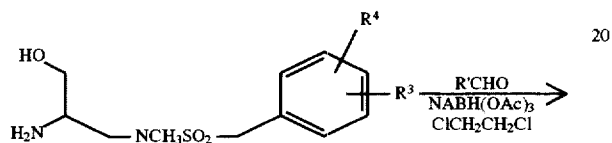
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SCHEME 12

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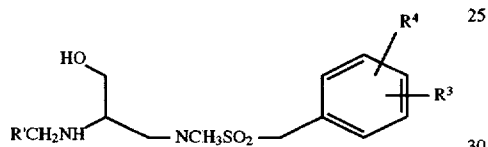
SCHEME 13



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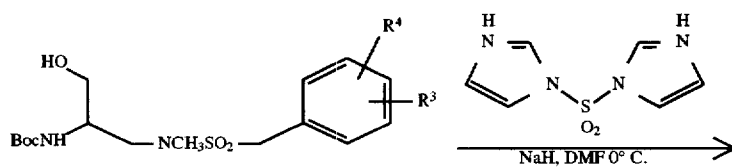
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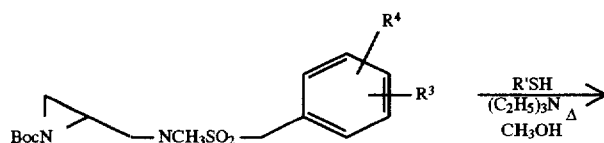
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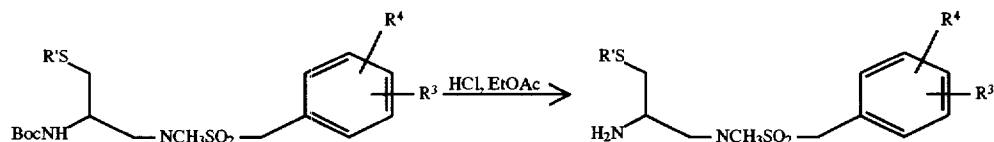
SCHEME 14



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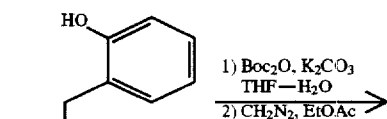


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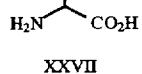


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SCHEME 15

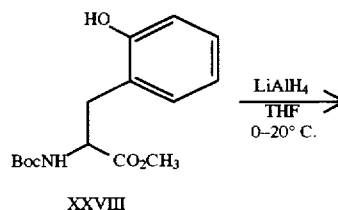


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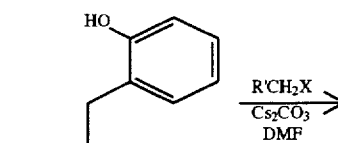


XXVII

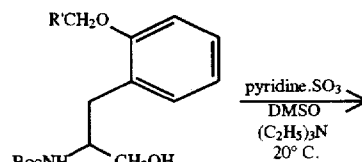
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SCHEME 15

XXVIII



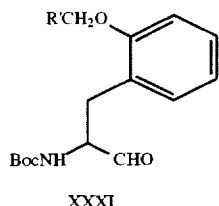
XXIX

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SCHEME 15

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XXX

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SCHEME 15

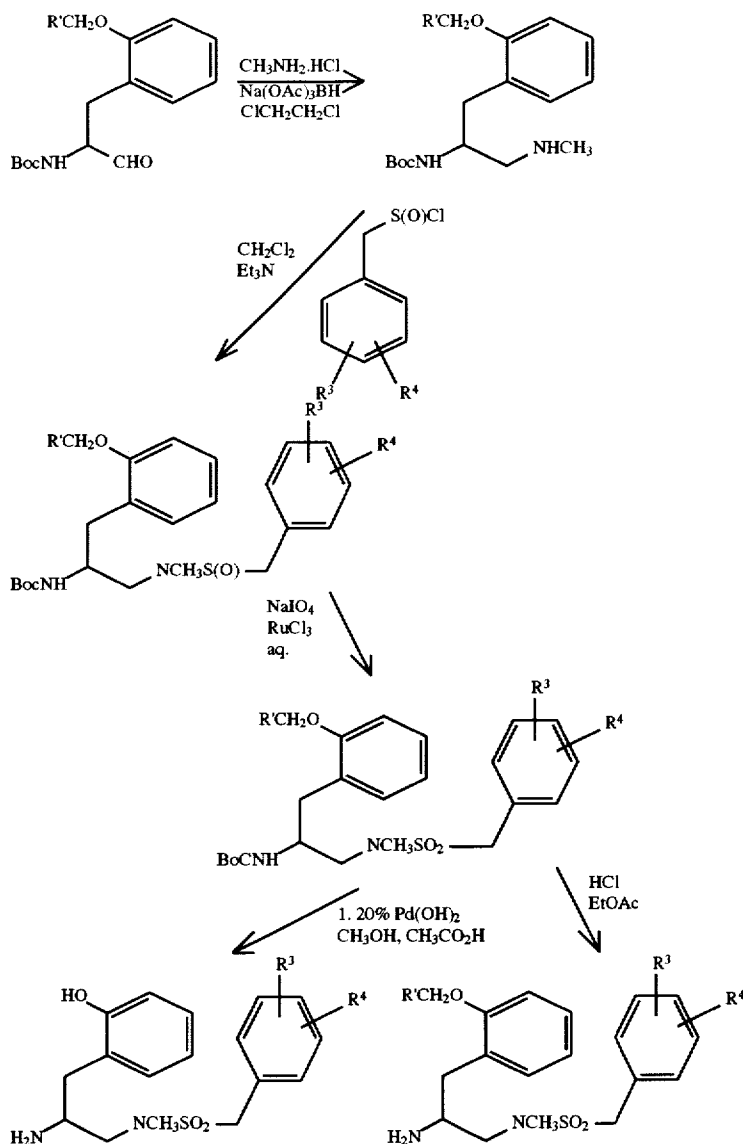
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proteins that can regulate Ras activity (i.e., neurofibromin (NF-1), neu. scr. abl. lck. fyn) or by other mechanisms.

The compounds of the instant invention inhibit farnesyl-protein transferase and farnesylation of the oncogene protein Ras. The instant compounds may also inhibit tumor angiogenesis, thereby affecting the growth of tumors (J. Rak et al. *Cancer Research*, 55:4575-4580 (1995)). Such anti-angiogenic properties of the instant compounds may also be useful in the treatment of certain forms of blindness related to retinal vascularization.

The compounds of this invention are also useful for inhibiting other diseases where Ras proteins are aberrantly

SCHEME 16



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The instant compounds are useful in the treatment of cancer. Cancers which may be treated with the compounds of this invention include, but are not limited to, colorectal carcinoma, exocrine pancreatic carcinoma, myeloid leukemias and neurological tumors. Such tumors may arise by mutations in the ras genes themselves, mutations in the

activated as a result of oncogenic mutation in other genes (i.e., the Ras gene itself is not activated by mutation to an oncogenic form) with said inhibition being accomplished by the administration of an effective amount of the compounds of the invention to a mammal in need of such treatment. For example, a component of NF-1 is a benign proliferative disorder.

The instant compounds may also be useful in the treatment of viral infections, in particular in the treatment of hepatitis delta and related viruses (J. S. Glenn et al. *Science*, 256:1331-1333 (1992)).

The compounds of the instant invention are also useful in the prevention of restenosis after percutaneous transluminal coronary angioplasty by inhibiting neointimal formation (C. Indolfi et al. *Nature medicine*, 1:541-545(1995)).

The instant compounds may also be useful in the treatment and prevention of polycystic kidney disease (D. L. Schaffner et al. *American Journal of Pathology*, 142:1051-1060 (1993) and B. Cowley, Jr. et al. *FASEB Journal*, 2:A3160 (1988)).

The instant compounds may also be useful for the treatment of fungal infections.

The compounds of this invention may be administered to mammals, preferably humans, either alone or, preferably, in combination with pharmaceutically acceptable carriers or diluents, in the form of a pharmaceutical composition, which is comprised of a compound of formula I in combination with a pharmaceutically acceptable carrier. The compounds can be administered orally, topically, rectally, vaginally, transdermally or parenterally, including the intravenous, intramuscular, intraperitoneal and subcutaneous routes of administration.

For oral use, the compound is administered, for example, in the form of tablets or capsules, or as a solution or suspension. In the case of tablets for oral use, carriers which are commonly used include lactose and corn starch; lubricating agents, such as magnesium stearate, are commonly added. For oral administration in capsule form, diluents also include lactose and dried corn starch. When aqueous suspensions are required for oral use, the active ingredient is combined with emulsifying and suspending agents. If desired, certain sweetening and/or flavoring agents may be added. For intramuscular, intra-peritoneal, subcutaneous and intravenous use, sterile solutions of the active ingredient are usually prepared, the pH of the solution is suitably adjusted and the product is buffered. For intravenous use, the total concentration is controlled to render the preparation substantially isotonic.

The compounds of the instant invention may also be co-administered with other well known therapeutic agents that are selected for their particular usefulness against the condition that is being treated. For example, the instant compounds may be useful in combination with known anti-cancer and cytotoxic agents. Similarly, the instant compounds may be useful in combination with agents that are effective in the treatment and prevention of NF-1, restinosis, polycystic kidney disease, infections of hepatitis delta and related viruses and fungal infections.

If formulated as a fixed dose, such combination products employ a compound of this invention substantially within the dosage range described below and other pharmaceutically active agent(s) typically within the acceptable dosage range. Compounds of the instant invention may alternatively be used sequentially with known pharmaceutically acceptable agent(s) when a combination formulation is inappropriate.

The daily dosage will normally be determined by the prescribing physician, who may vary the dosage according to the age, weight, and response of the individual patient, as well as the severity of the patient's condition.

In one exemplary application, a suitable amount of compound is administered to a mammal undergoing treatment for cancer. Administration occurs in an amount between

about 0.1 mg/kg of body weight to about 60 mg/kg of body weight per day, preferably of between 0.5 mg/kg of body weight to about 40 mg/kg of body weight per day.

The compounds of the instant invention are also useful as a component in an assay to rapidly determine the presence and quantity of farnesyl-protein transferase (FPTase) in a composition. Thus the composition to be tested may be divided and the two portions contacted with mixtures which comprise a known substrate of FPTase (for example a tetrapeptide having a cysteine at the amine terminus) and farnesyl pyrophosphate and, in one of the mixtures, a compound of the instant invention. After the assay mixtures are incubated for an sufficient period of time, well known in the art, to allow the FPTase to farnesylate the substrate, the chemical content of the assay mixtures may be determined by well known immunological, radiochemical or chromatographic techniques. Because the compounds of the instant invention are selective inhibitors of FPTase, absence or quantitative reduction of the amount of substrate in the assay mixture without the compound of the instant invention relative to the presence of the unchanged substrate in the assay containing the instant compound is indicative of the presence of FPTase in the composition to be tested.

It would be readily apparent to one of ordinary skill in the art that such an assay as described above would be useful in identifying tissue samples which contain farnesyl-protein transferase and quantitating the enzyme. Thus, potent inhibitor compounds of the instant invention may be used in an active site titration assay to determine the quantity of enzyme in the sample. A series of samples composed of aliquots of a tissue extract containing an unknown amount of farnesyl-protein transferase, an excess amount of a known substrate of FPTase (for example a tetrapeptide having a cysteine at the amine terminus) and farnesyl pyrophosphate are incubated for an appropriate period of time in the presence of varying concentrations of a compound of the instant invention. The concentration of a sufficiently potent inhibitor (i.e., one that has a K_i substantially smaller than the concentration of enzyme in the assay vessel) required to inhibit the enzymatic activity of the sample by 50% is approximately equal to half of the concentration of the enzyme in that particular sample.

EXAMPLE 1

N-[1-(4-Cyanobenzyl)Imidazolyl-5-Methyl]-N-(Methyl)-3-Chlorobenzylsulfonamide Hydrochloride

Step A: Preparation of 1-triphenylmethyl-4-(hydroxymethyl)imidazole

To a solution of 4-(hydroxymethyl)imidazole hydrochloride (35.0 g, 260 mmol) in 250 mL of dry DMF at room temperature was added triethylamine (90.6 mL, 650 mmol). A white solid precipitated from the solution. Chlorotriphenylmethane (76.1 g, 273 mmol) in 500 mL of DMF was added dropwise. The reaction mixture was stirred for 20 hours, poured over ice, filtered, and washed with ice water. The resulting product was slurried with cold dioxane, filtered, and dried in vacuo to provide the titled product as a white solid which was sufficiently pure for use in the next step.

Step B: Preparation of 1-triphenylmethyl-4-(acetoxymethyl)imidazole

Alcohol from Step A (260 mmol, prepared above) was suspended in 500 mL of pyridine. Acetic anhydride (74 mL, 780 mmol) was added dropwise, and the reaction was stirred for 48 hours during which it became homogeneous. The solution was poured into 2 L of EtOAc, washed with water

(3×1 L), 5% aq. HCl soln. (2×1 L), sat. aq. NaHCO₃, and brine, then dried (Na₂SO₄), filtered, and concentrated in vacuo to provide the crude product. The acetate was isolated as a white powder (85.8 g, 86% yield for two steps) which was sufficiently pure for use in the next reaction.

Step C: Preparation of 1-(4-cyanobenzyl)-5-(acetoxymethyl)imidazole hydrobromide

A solution of the product from Step B (85.8 g, 225 mmol) and α-bromo-p-tolunitrile (50.1 g, 232 mmol) in 500 mL of EtOAc was stirred at 60° C. for 20 hours, during which a pale yellow precipitate formed. The reaction was cooled to room temperature and filtered to provide the solid imidazolium bromide salt. The filtrate was concentrated in vacuo to a volume 200 mL, reheated at 60° C. for two hours, cooled to room temperature, and filtered again. The filtrate was concentrated in vacuo to a volume 100 mL, reheated at 60° C. for another two hours, cooled to room temperature, and concentrated in vacuo to provide a pale yellow solid. All of the solid material was combined, dissolved in 500 mL of methanol, and warmed to 60° C. After two hours, the solution was reconcentrated in vacuo to provide a white solid which was triturated with hexane to remove soluble materials. Removal of residual solvents in vacuo provided the titled product hydrobromide as a white solid (50.4 g, 67% yield, 89% purity by HPLC) which was used in the next step without further purification.

Step D: Preparation of 1-(4-cyanobenzyl)-5-(hydroxymethyl)imidazole

To a solution of the acetate from Step C (50.4 g, 150 mmol) in 1.5 L of 3:1 THF/water at 0° C. was added lithium hydroxide monohydrate (18.9 g, 450 mmol). After one hour, the reaction was concentrated in vacuo, diluted with EtOAc (3 L), and washed with water, sat. aq. NaHCO₃ and brine. The solution was then dried (Na₂SO₄), filtered, and concentrated in vacuo to provide the crude product (26.2 g, 82% yield) as a pale yellow fluffy solid which was sufficiently pure for use in the next step without further purification.

Step E: Preparation of 1-(4-cyanobenzyl)-5-imidazolecarboxaldehyde

To a solution of the alcohol from Step D (21.5 g, 101 mmol) in 500 mL of DMSO at room temperature was added triethylamine (56 mL, 402 mmol), then SO₃-pyridine complex (40.5 g, 254 mmol). After 45 minutes, the reaction was poured into 2.5 L of EtOAc, washed with water (4×1 L) and brine, dried (Na₂SO₄), filtered, and concentrated in vacuo to provide the aldehyde (18.7 g, 88% yield) as a white powder which was sufficiently pure for use in the next step without further purification.

Step F: Preparation of 1-(4-cyanobenzyl)-5-[(methylamino)methyl]imidazole

To a suspension of methylamine hydrochloride in 5 mL dichloroethane at 0° C. are added 4 Å sieves (0.5 g), followed by 1 mmol of the aldehyde from Step E and 1.5 mmol Na(OAc)₃BH. The reaction is stirred for 10 minutes at 0° C., warmed to room temperature and stirred for 2 hours. The reaction is poured into EtOAc/ sat. NaHCO₃ solution. The organic layer is washed with brine, dried (Na₂SO₄), filtered, and concentrated in vacuo. The crude product is taken up in 10 mL dichloromethane and 2 mL n-propylamine, stirred at room temperature for 1 hour, concentrated in vacuo, and purified by flash chromatography.

Step G: Preparation of 3-chlorobenzyl thioacetate

To a solution of 1 mmol 3-chlorobenzyl alcohol and 1 mmol triphenylphosphine in 5 mL THF at 0° C., 1 mmol diethylazodicarboxylate is added. After stirring for 10 minutes, 1 mmol thioacetic acid is added. The reaction is

stirred for 3 hours, concentrated and purified by flash chromatography.

Step H: Preparation of 3-chlorobenzylsulfinyl chloride

To a -20° C. solution of the thioester from Step G (1 mmol) in 3 mL of dichloromethane under argon are added 1 mmol acetic anhydride and 2 mmol sulfonyl chloride. The reaction is stirred for 1 hr during which time the temperature is allowed to rise to -5° C. The mixture is concentrated in vacuo and the crude product used for coupling in the next step.

Step I: Preparation of N-[1-(4-cyanobenzyl)imidazolyl-5-methyl]-N-(methyl)-3-chlorobenzylsulfonamide

To a 0° C. solution of the sulfinyl chloride from Step H (1 mmol) in 4 mL dichloromethane is added a solution of 1 mmol triethylamine and 1 mmol of the amine from Step F in 2 mL dichloromethane. The reaction is stirred overnight and the temperature is allowed to rise to room temperature. This mixture is poured into ethyl acetate, washed with sat. NaHCO₃ solution and brine, dried with Na₂SO₄, concentrated and purified by flash chromatography.

Step J: Preparation of N-[1-(4-cyanobenzyl)imidazolyl-5-methyl]-N-(methyl)-3-chlorobenzylsulfonamide hydrochloride

A solution of the sulfonamide from Step I (1 mmol) in 2 mL acetonitrile is cooled to 0° C. NaIO₄ is added (1.5 mmol) followed by a catalytic amount of RuCl₃·3H₂O and 2 mL H₂O. The reaction is stirred at room temperature for 1 hour, diluted with EtOAc, and washed with sat. NaHCO₃ solution and brine, dried (Na₂SO₄), filtered and concentrated. The resulting product is purified by flash chromatography, then taken up in dichloromethane, and treated with excess ethereal HCl. Concentration in vacuo provides the titled product.

EXAMPLE 2

N-(3-Chlorobenzyl)-1-[(4-Cyanobenzyl)-5-Imidazolyl]Methylsulfonamide Hydrochloride

Step A: Preparation of 1-(4-chlorobenzyl)-5-imidazolylmethyl sulfinyl chloride

The titled compound is prepared from the alcohol from Step D of Example 1 by the methods described in Steps G and H of Example 1.

Step B: Preparation of N-(3-chlorobenzyl)-1-[(4-cyanobenzyl)-5-imidazolyl]methylsulfonamide

The sulfinyl chloride from Step A is coupled with 3-chlorobenzylamine using the method described in Step I of Example 1.

Step C: Preparation of N-(3-chlorobenzyl)-1-[(4-cyanobenzyl)-5-imidazolyl]methylsulfonamide hydrochloride

The sulfonamide from Step B is oxidized to the sulfonamide and converted to the HCl salt using the method described in Step J of Example 1.

EXAMPLE 3

N-[3-(4-Cyanobenzyl)Pyridyl-4-Methyl]-N-(Methyl)-3-Chlorobenzylsulfonamide Hydrochloride

Step A: Preparation of 3-(4-cyanobenzyl)pyridin-4-carboxylic acid methyl ester

A solution of 4-cyanobenzyl bromide (625 mg, 3.27 mmol) in dry THF (4mL) was added slowly over ~3 min. to a suspension of activated Zn (dust; 250 mg) in dry THF (2 mL) at 0° under an argon atmosphere. The ice-bath was removed and the slurry was stirred at room temperature for a further 30 min. Then 3-bromopyridin-4-carboxylic acid methyl ester (540 mg, 2.5 mmol) followed by dichlorobis

(triphenylphosphine)nickel (II) (50 mg). The resultant reddish-brown mixture was stirred for 3 h at -40° – -45° C. The mixture was cooled and distributed between EtOAc (100 ml) and 5% aqueous citric acid (50 mL). The organic layer was washed with H_2O (2×50 mL), dried with Na_2SO_4 . After evaporation of the solvent the residue was purified on silica gel, eluting with 35% EtOAc in hexane to give 420 mg as a clear gum. FAB ms (M+1) 253.

Step B: Preparation of 3-(4-cyanobenzyl)-4-(hydroxymethyl)pyridine

The title compound was obtained by sodium borohydride (300 mg) reduction of the ester from Step A (415 mg) in methanol (5 mL) at room temperature. After stirring for 4 h the solution was evaporated and the product was purified on silica gel, eluting with 2% methanol in chloroform to give the title compound. FAB ms (M+1) 225.

Step C: Preparation of 3-(4-cyanobenzyl)-4-pyridinal

The title compound was obtained by activated manganese dioxide (1.0 g) oxidation of the alcohol from Step B (240 mg, 1.07 mmol) in dioxane (10 mL) at reflux for 30 min. Filtration and evaporation of the solvent provided title compound, mp 80° – 83° C.

Step D: Preparation of 3-(4-cyanobenzyl)-4-[(methylamino)methyl]pyridine

The titled compound is prepared from the pyridinal from Step C and methylamine hydrochloride using the procedure in Step F of Example 1.

Step E: Preparation of N-[3-(4-cyanobenzyl)pyridyl]-4-methyl-N-(methyl)-3-chlorobenzylsulfonamide hydrochloride

The titled compound is prepared from the amine from Step D and the sulfinyl chloride from Step H of Example 1 using the procedures described in Steps I and J of Example 1.

In vitro inhibition of ras farnesyl transferase

Assays of farnesyl-protein transferase. Partially purified bovine FPTase and Ras peptides (Ras-CVLS, Ras-CVIM and Ras-CAIL) were prepared as described by Schaber et al., *J. Biol. Chem.* 265:14701–14704 (1990), Pompliano, et al., *Biochemistry* 31:3800 (1992) and Gibbs et al., *PNAS* U.S.A. 86:6630–6634 (1989), respectively. Bovine FPTase was assayed in a volume of 100 μ l containing 100 mM N-(2-hydroxy ethyl) piperazine-N'-(2-ethane sulfonic acid) (HEPES), pH 7.4, 5 mM $MgCl_2$, 5 mM dithiothreitol (DTT), 100 mM [3H]-farnesyl diphosphate ([3H]-FPP; 740 CBq/mmol, New England Nuclear), 650 nM Ras-CVLS and 10 μ g/ml FPTase at 31° C. for 60 min. Reactions were initiated with FPTase and stopped with 1 ml of 1.0M HCL in ethanol. Precipitates were collected onto filter-mats using a TomTec Mach II cell harvester, washed with 100% ethanol, dried and counted in an LKB β -plate counter. The assay was linear with respect to both substrates, FPTase levels and time; less than 10% of the [3H]-FPP was utilized during the reaction period. Purified compounds were dissolved in 100% dimethyl sulfoxide (DMSO) and were diluted 20-fold into the assay. Percentage inhibition is measured by the amount of incorporation of radioactivity in the presence of the test compound when compared to the amount of incorporation in the absence of the test compound.

Human FPTase was prepared as described by Omer et al., *Biochemistry* 32:5167–5176 (1993). Human FPTase activity was assayed as described above with the exception that 0.1% (w/v) polyethylene glycol 20,000, 10 μ M $ZnCl_2$ and 100 nM Ras-CVIM were added to the reaction mixture. Reactions were performed for 30 min., stopped with 100 μ l of 30% (v/v) trichloroacetic acid (TCA) in ethanol and processed as described above for the bovine enzyme.

In vivo ras farnesylation assay

The cell line used in this assay is a v-ras line derived from either Rat1 or NIH3T3 cells, which expressed viral Ha-ras p21. The assay is performed essentially as described in DeClue, J. E. et al., *Cancer Research* 51:712–717, (1991). Cells in 10 cm dishes at 50–75% confluency are treated with the test compound (final concentration of solvent, methanol or dimethyl sulfoxide, is 0.1%). After 4 hours at 37° C., the cells are labelled in 3 ml methionine-free DMEM supplemented with 10% regular DMEM, 2% fetal bovine serum and 400 mCi [^{35}S]methionine (1000 Ci/mmol). After an additional 20 hours, the cells are lysed in 1 ml lysis buffer (1% NP40/20 mM HEPES, pH 7.5/5 mM $MgCl_2$ /1 mM DTT/10 mg/ml aprotinin/2 mg/ml leupeptin/2 mg/ml antipain/0.5 mM PMSF) and the lysates cleared by centrifugation at $100,000 \times g$ for 45 min. Aliquots of lysates containing equal numbers of acid-precipitable counts are brought to 1 ml with IP buffer (lysis buffer lacking DTT) and immunoprecipitated with the ras-specific monoclonal antibody Y13-259 (Furth, M. E. et al., *J. Virol.* 43:294–304, (1982)). Following a 2 hour antibody incubation at 4° C., 200 μ l of a 25% suspension of protein A-Sepharose coated with rabbit anti rat IgG is added for 45 min. The immunoprecipitates are washed four times with IP buffer (20 mM HEPES, pH 7.5/1 mM EDTA/1% Triton X-100/0.5% deoxycholate/0.1% SDS/0.1M NaCl) boiled in SDS-PAGE sample buffer and loaded on 13% acrylamide gels. When the dye front reached the bottom, the gel is fixed, soaked in Enlightening, dried and autoradiographed. The intensities of the bands corresponding to farnesylated and nonfarnesylated ras proteins are compared to determine the percent inhibition of farnesyl transfer to protein.

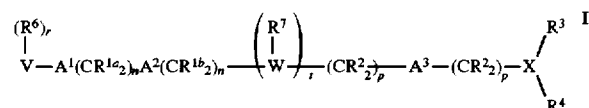
In vivo growth inhibition assay

To determine the biological consequences of FPTase inhibition, the effect of the compounds of the instant invention on the anchorage-independent growth of Rat1 cells transformed with either a v-ras, v-raf, or v-mos oncogene is tested. Cells transformed by v-Raf and v-Mos maybe included in the analysis to evaluate the specificity of instant compounds for Ras-induced cell transformation.

Rat 1 cells transformed with either v-ras, v-raf, or v-mos are seeded at a density of 1×10^4 cells per plate (35 mm in diameter) in a 0.3% top agarose layer in medium A (Dulbecco's modified Eagle's medium supplemented with 10% fetal bovine serum) over a bottom agarose layer (0.6%). Both layers contain 0.1% methanol or an appropriate concentration of the instant compound (dissolved in methanol at 1000 times the final concentration used in the assay). The cells are fed twice weekly with 0.5 ml of medium A containing 0.1% methanol or the concentration of the instant compound. Photomicrographs are taken 16 days after the cultures are seeded and comparisons are made.

What is claimed is:

1. A compound represented by formula I:



or a pharmaceutically acceptable salt thereof, wherein:

R^{1a} , R^{1b} and R^2 are independently selected from the group consisting of: hydrogen, aryl, heterocyclyl, C_3 – C_{10} cycloalkyl, C_2 – C_6 alkenyl, C_2 – C_6 alkynyl, R^8O —, $R^9S(O)_m$ —, $(R^8)_2NC(O)$ —, $R^8C(O)NR^8$ —, CN , NO_2 , $(R^8)_2NC(NR^8)$ —, $R^8C(O)$ —, $R^8OC(O)$ —, N_3 , $—N(R^8)_2$, $R^9OC(O)NR^8$ — and C_1 – C_6 alkyl, unsubstituted or substituted by 1–3 groups selected

from the group consisting of: halo, aryl, heterocyclyl, C₃-C₁₀ cycloalkyl, C₂-C₆ alkenyl, C₂-C₆ alkynyl, R⁸O—, R⁹S(O)_m—, R⁸C(O)NR⁸—, CN, (R⁸)₂NC(NR⁸)—, R⁸C(O)—, R⁸OC(O)—, N₃, —N(R⁸)₂ and R⁹OC(O)NR⁸—;

R³ and R⁴ are independently selected from the group consisting of: H, F, Cl, Br, —NR⁸₂, CF₃, NO₂, R⁸O—, R⁹S(O)_m—, (R⁸)₂NC(O)—, R⁸C(O)NH—, H₂NC(NH)—, R⁸C(O)—, R⁸OC(O)—, N₃, CN, R⁹OC(O)NR⁸—, C₁-C₂₀ alkyl, substituted or unsubstituted aryl and substituted or unsubstituted heterocyclyl;

A³ is selected from: —NR⁵S(O)_m— or —S(O)_mNR⁵—, with m equal to 0, 1 or 2, and R⁵ selected from the group consisting of: hydrogen, unsubstituted or substituted aryl, unsubstituted or substituted heterocyclyl, unsubstituted or substituted C₃-C₁₀ cycloalkyl, and C₁-C₆ alkyl, unsubstituted or substituted with 1-3 members selected from the group consisting of: unsubstituted or substituted aryl, unsubstituted or substituted heterocyclyl, unsubstituted or substituted C₃-C₁₀ cycloalkyl, —N(R⁸)₂, —CF₃, —NO₂, (R⁸)O—, (R⁹)S(O)_m—, (R⁸)C(O)NH—, H₂NC(NH)—, (R⁸)C(O)—, (R⁸)OC(O)—, N₃, CN and (R⁹)OC(O)NR⁸—;

R⁶ and R⁷ are independently selected from the group consisting of: hydrogen, aryl, heterocyclyl, C₃-C₁₀ cycloalkyl, C₂-C₆ alkenyl, C₂-C₆ alkynyl, C₁-C₆ perfluoroalkyl, F, Cl, Br, R⁸O—, R⁹S(O)_m—, R⁸C(O)NR⁸—, CN, NO₂, (R⁸)₂NC(NR⁸)—, R⁸C(O)—, R⁸OC(O)—, N₃, —N(R⁸)₂, R⁹OC(O)NR⁸— and C₁-C₆ alkyl unsubstituted or substituted by 1-3 groups selected from: aryl, heterocyclyl, C₃-C₁₀ cycloalkyl, C₂-C₆ alkenyl, C₂-C₆ alkynyl, perfluoroalkyl, F, Cl, Br, R⁸O—, R⁹S(O)_m—, R⁸C(O)NR⁸—, CN, (R⁸)₂NC(NR⁸)—, R⁸C(O)—, R⁸OC(O)—, N₃, —N(R⁸)₂ and R⁹OC(O)NR⁸—;

each R⁸ is independently selected from hydrogen, C₁-C₆ alkyl, aryl and aralkyl;

each R⁹ is independently selected from C₁-C₆ alkyl and aryl;

A¹ and A² are independently selected from the group consisting of: a bond, —CH=CH—, —C≡C—, —C(O)—, —C(O)NR⁸—, —NR⁸C(O)—, —O—, —N(R⁸)—, —S(O)₂N(R⁸)—, —N(R⁸)S(O)₂—, and S(O)_m;

X represents aryl or heteroaryl;

V is selected from the group consisting of: hydrogen, heterocyclyl, aryl, C₁-C₂₀ alkyl wherein from 0 to 4 carbon atoms are replaced with a heteroatom selected from O, S, and N, and C₂-C₂₀ alkenyl, provided that V is not hydrogen if A¹ is S(O)_m and V is not hydrogen if A¹ is a bond, n is 0 and A² is S(O)_m;

W represents heterocyclyl;

each n and p independently represents 0, 1, 2, 3 or 4;

r is 0 to 5, provided that r is 0 when V is hydrogen, and t is 1.

2. A compound in accordance with claim 1 wherein R^{1a}, R^{1b} and R² are independently selected from the group consisting of: hydrogen, —N(R⁸)₂, R⁸C(O)NR⁸— and C₁-C₆ alkyl, unsubstituted or substituted with 1-2 groups selected from unsubstituted or substituted aryl, —N(R⁸)₂, R⁸O— and R⁸C(O)NR⁸—.

3. A compound in accordance with claim 1 wherein R³ and R⁴ are selected from: hydrogen and C₁-C₆ alkyl.

4. A compound in accordance with claim 1 wherein A³ represents NR⁵S(O)_m—, in which m represents 2 and R⁵ represents hydrogen.

5. A compound in accordance with claim 1 wherein R⁶ represents hydrogen, unsubstituted or substituted C₁-C₆ alkyl.

6. A compound in accordance with claim 1 wherein R⁷ represents H or unsubstituted C₁-C₆ alkyl.

7. A compound in accordance with claim 1 wherein R⁸ represents H or C₁-C₆ alkyl, and R⁹ is C₁-C₆ alkyl.

8. A compound in accordance with claim 1 wherein A¹ and A² are independently selected from: a bond, —C(O)NR⁸—, —NR⁸C(O)—, —O—, —N(R⁸)—, —S(O)₂N(R⁸)— and —N(R⁸)S(O)₂—.

9. A compound in accordance with claim 1 wherein V is selected from hydrogen, heterocyclyl and aryl.

10. A compound in accordance with claim 1 wherein V represents phenyl.

11. A compound in accordance with claim 1 wherein X represents aryl.

12. A compound in accordance with claim 11 wherein X represents phenyl.

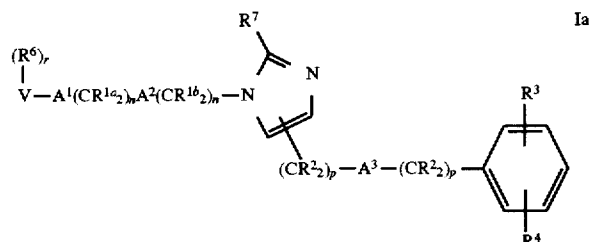
13. A compound in accordance with claim 1 wherein W is heterocyclyl selected from the group consisting of: imidazolyl, imidazolyl, oxazolyl, pyrazolyl, pyrrolidinyl, thiazolyl and pyridyl.

14. A compound in accordance with claim 10 wherein W is selected from imidazolyl and pyridyl.

15. A compound in accordance with claim 1 wherein m is 0 or 2.

16. A compound in accordance with claim 1 wherein n and p are 0, 1, 2 or 3.

17. A compound in accordance with claim 1 represented by formula Ia:



wherein:

R³, R⁴, A³, R⁸, R⁹, m, n, p and r are as originally defined; each R^{1a} and R² is independently selected from hydrogen and C₁-C₆ alkyl;

each R^{1b} is independently selected from: hydrogen, aryl, heterocyclyl, C₃-C₁₀ cycloalkyl, C₂-C₆ alkenyl, R⁸O—, —N(R⁸)₂ and C₁-C₆ alkyl unsubstituted or substituted by aryl, heterocyclyl, cycloalkyl, alkenyl, R⁸O— and —N(R⁸)₂;

R⁵ is selected from the group consisting of: hydrogen and C₁-C₆ alkyl, unsubstituted or substituted with 1-3 members selected from the group consisting of: unsubstituted or substituted aryl, unsubstituted or substituted heterocyclyl, unsubstituted or substituted C₃-C₁₀ cycloalkyl, —N(R⁸)₂, —CF₃, —NO₂, (R⁸)O—, (R⁹)S(O)_m—, (R⁸)C(O)NH—, H₂NC(NH)—, (R⁸)C(O)—, (R⁸)OC(O)—, N₃, CN and (R⁹)OC(O)NR⁸—;

R⁶ is independently selected from: hydrogen, C₁-C₆ alkyl, C₂-C₆ alkenyl, C₂-C₆ alkynyl, C₁-C₆ perfluoroalkyl, F, Cl, R⁸O—, R⁸C(O)NR⁸—, CN, NO₂, (R⁸)₂N—C(NR⁸)—, R⁸C(O)—, R⁸OC(O)—, —N(R⁸)₂, or R⁹OC(O)NR⁸—, and C₁-C₆ alkyl substituted by C₁-C₆ perfluoroalkyl, R⁸O—, R⁸C(O)NR⁸—, (R⁸)₂N—C(NR⁸)—, R⁸C(O)—, R⁸OC(O)—, —N(R⁸)₂ and R⁹OC(O)NR⁸—;

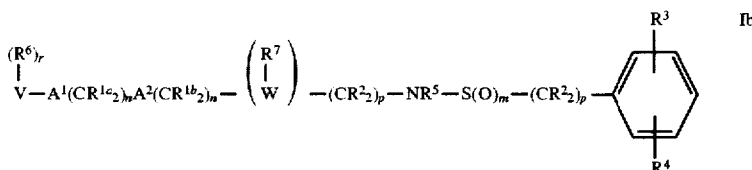
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R^7 is H or unsubstituted C_{1-6} alkyl;

A^1 and A^2 are independently selected from: a bond, $-\text{CH}=\text{CH}-$, $-\text{C}\equiv\text{C}-$, $-\text{C}(\text{O})-$, $-\text{C}(\text{O})\text{NR}^8-$, O, $-\text{N}(\text{R}^8)-$ and $\text{S}(\text{O})_m$;

and V is selected from: hydrogen; aryl; heterocyclyl selected from pyrrolidinyl, imidazolyl, pyridinyl, thiazolyl, pyridonyl, 2-oxopiperidinyl, indolyl, quinolinyl, isoquinolinyl and thienyl; C_1-C_{20} alkyl wherein from 0 to 4 carbon atoms are replaced with a heteroatom selected from O, S, and N, and C_2-C_{20} alkenyl, provided that V is not hydrogen if A^1 is $\text{S}(\text{O})_m$ and V is not hydrogen if A^1 is a bond and A^2 is $\text{S}(\text{O})_m$.

18. A compound in accordance with claim 1 represented by formula Ib:



wherein:

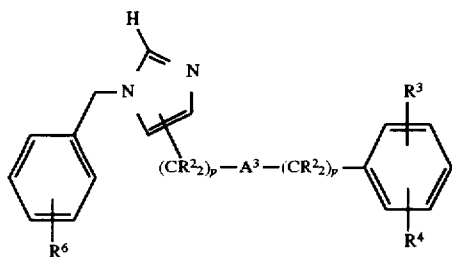
R^{1a} , R^{1b} , R^2 , A^1 , A^2 , R^3 , R^4 , R^5 , R^6 , R^8 , R^9 , m, n, p and r are as originally defined;

R^7 is selected from: hydrogen and unsubstituted C_1-C_6 alkyl;

V is selected from: hydrogen, heterocyclyl selected from pyrrolidinyl, imidazolyl, pyridinyl, thiazolyl, pyridonyl, 2-oxopiperidinyl, indolyl, quinolinyl, isoquinolinyl, and thienyl, aryl, C_1-C_{20} alkyl wherein from 0 to 4 carbon atoms are replaced with a heteroatom selected from O, S, and N, and C_2-C_{20} alkenyl, provided that V is not hydrogen if A^1 is $\text{S}(\text{O})_m$ and V is not hydrogen if A^1 is a bond, n is 0 and A^2 is $\text{S}(\text{O})_m$; and

W represents heterocyclyl selected from pyrrolidinyl, pyridinyl, thiazolyl, pyridonyl, 2-oxopiperidinyl, indolyl, quinolinyl and isoquinolinyl.

19. A compound in accordance with claim 1 represented by formula Ic:



wherein:

each R^2 is independently selected from hydrogen and C_1-C_6 alkyl;

R^3 , R^4 , A^3 , R^8 , R^9 , m and p are as originally defined;

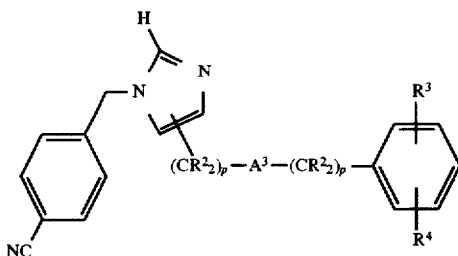
each R^5 is selected from: hydrogen and C_1-C_6 alkyl unsubstituted or substituted with 1-3 groups selected from unsubstituted or substituted aryl, unsubstituted or substituted heterocyclyl, unsubstituted or substituted C_3-C_{10} cycloalkyl, $-\text{N}(\text{R}^8)_2$, $-\text{CF}_3$, $-\text{NO}_2$, $(\text{R}^8)\text{O}-$, $(\text{R}^9)\text{S}(\text{O})_m-$, $(\text{R}^8)\text{C}(\text{O})\text{NH}-$, $\text{H}_2\text{NC}(\text{NH})-$, $(\text{R}^8)\text{C}(\text{O})-$, $(\text{R}^8)\text{OC}(\text{O})-$, N_3 , $-\text{CN}$ and $(\text{R}^9)\text{OC}(\text{O})\text{NR}^8-$;

36

and R^6 is selected from the group consisting of: hydrogen,

C_1-C_6 alkyl, C_2-C_6 alkenyl, C_2-C_6 alkynyl, C_1-C_6 perfluoroalkyl, F, Cl, $\text{R}^8\text{O}-$, $\text{R}^8\text{C}(\text{O})\text{NR}^8-$, CN, NO_2 , $(\text{R}^8)_2\text{N}-\text{C}(\text{NR}^8)-$, $\text{R}^8\text{C}(\text{O})-$, $\text{R}^8\text{OC}(\text{O})-$, $-\text{N}(\text{R}^8)_2$, or $\text{R}^9\text{OC}(\text{O})\text{NR}^8-$ and C_1-C_6 alkyl substituted by C_1-C_6 perfluoroalkyl, $\text{R}^8\text{O}-$, $\text{R}^8\text{C}(\text{O})\text{NR}^8-$, $(\text{R}^8)_2\text{N}-\text{C}(\text{NR}^8)-$, $\text{R}^8\text{C}(\text{O})-$, $\text{R}^8\text{OC}(\text{O})-$, $-\text{N}(\text{R}^8)_2$ or $\text{R}^9\text{OC}(\text{O})\text{NR}^8-$.

20. A compound in accordance with claim 1 represented by formula Id:



wherein:

each R^2 is independently selected from: hydrogen and C_1-C_6 alkyl;

R^3 and R^4 are independently selected from H, F, Cl, Br, $\text{N}(\text{R}^8)_2$, CF_3 , NO_2 , $(\text{R}^8)\text{O}-$, $(\text{R}^9)\text{S}(\text{O})_m-$, $(\text{R}^8)\text{C}(\text{O})\text{NH}-$, $\text{H}_2\text{N}-\text{C}(\text{NH})-$, $(\text{R}^8)\text{C}(\text{O})-$, $(\text{R}^8)\text{OC}(\text{O})-$, N_3 , CN, $(\text{R}^9)\text{OC}(\text{O})\text{NR}^8-$, C_1-C_{20} alkyl, substituted or unsubstituted aryl, and substituted or unsubstituted heterocyclyl;

A^3 represents $-\text{NR}^5-\text{S}(\text{O})_m-$ or $-\text{S}(\text{O})_m-\text{NR}^5-$;

R^5 is selected from: hydrogen and C_1-C_6 alkyl, unsubstituted or substituted with a group selected from unsubstituted or substituted aryl, unsubstituted or substituted heterocyclyl, unsubstituted or substituted C_3-C_{10} cycloalkyl, $\text{N}(\text{R}^8)_2$, CF_3 , NO_2 , $(\text{R}^8)\text{O}-$, $(\text{R}^9)\text{S}(\text{O})_m-$, $(\text{R}^8)\text{C}(\text{O})\text{NH}-$, $\text{H}_2\text{N}-\text{C}(\text{NH})-$, $(\text{R}^8)\text{C}(\text{O})-$, $(\text{R}^8)\text{OC}(\text{O})-$, N_3 , CN, $(\text{R}^9)\text{OC}(\text{O})\text{NR}^8-$.

21. A pharmaceutical composition which comprises a compound in accordance with claim 1 in combination with a pharmaceutically acceptable carrier.

22. A method of inhibiting farnesyl-protein transferase in a mammalian patient in need of such treatment which comprises administering to said mammal a compound in accordance with claim 1.

23. A method of treating cancer in a mammalian patient in need of such treatment which comprises administering to said patient an anti-cancer effective amount of a compound in accordance with claim 1.

24. A method of treating cancer in accordance with claim 21, wherein the cancer treated is selected from colorectal carcinoma, exocrine pancreatic carcinoma, myeloid leukemia and neurological tumors.

37

25. A method of treating neurofibromin benign proliferative disorder in a mammalian patient in need of such treatment which comprises administering to said patient an effective amount of a compound of claim 1.

26. A method of treating blindness related to retinal vascularization in a mammalian patient in need of such treatment which comprises administering to said patient an amount of a compound of claim 1 which is effective for treating blindness related to retinal vascularization.

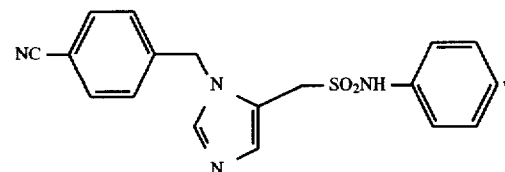
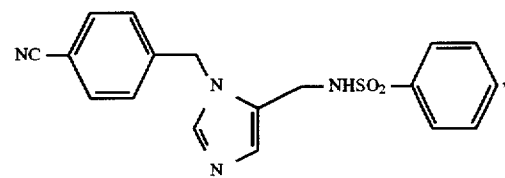
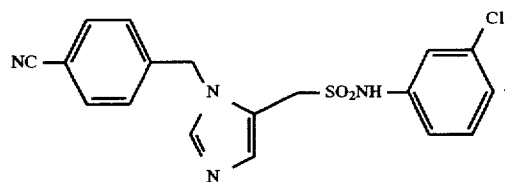
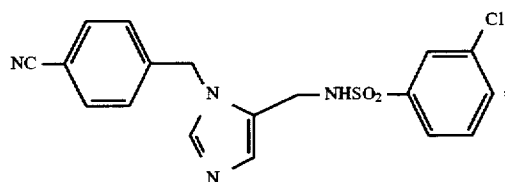
27. A method of treating hepatitis delta or a related viral infection in a mammalian patient in need of such treatment which comprises administering to said patient an anti-viral effective amount of a compound of claim 1.

28. A method of preventing restenosis in a mammalian patient in need of such treatment which comprises administering to said patient an amount of a compound of claim 1 which is effective for preventing restenosis.

29. A method of treating polycystic kidney disease in a mammalian patient in need of such treatment which comprises administering to said patient an amount of a compound of claim 1 which is effective for treating polycystic kidney disease.

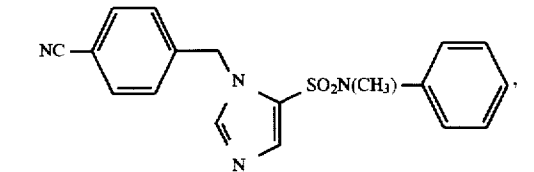
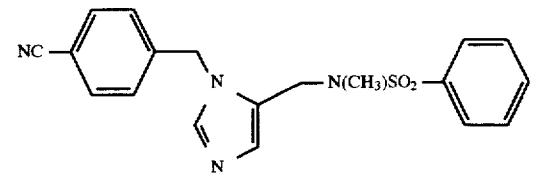
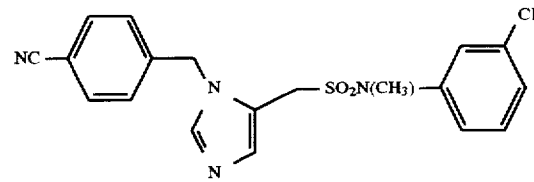
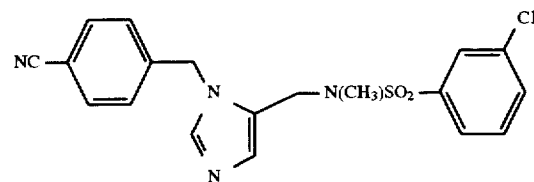
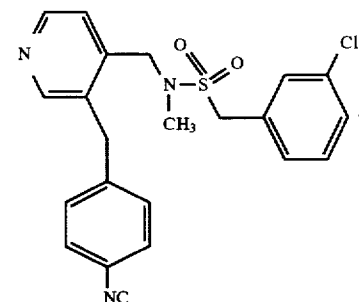
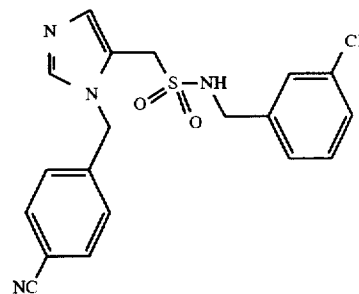
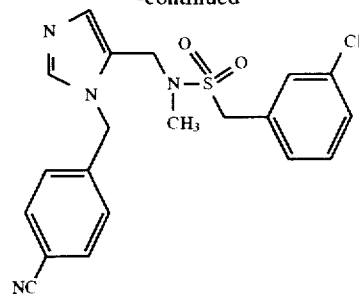
30. A method of treating or preventing a disease selected from cancer, neurofibromin benign proliferative disorder, blindness related to retinal vascularization, infections from hepatitis delta and related viruses, restenosis and polycystic kidney disease, in a mammalian patient in need of such treatment which comprises administering to said patient an effective amount of a compound of claim 1.

31. A compound in accordance with claim 1 represented by the formula:



38

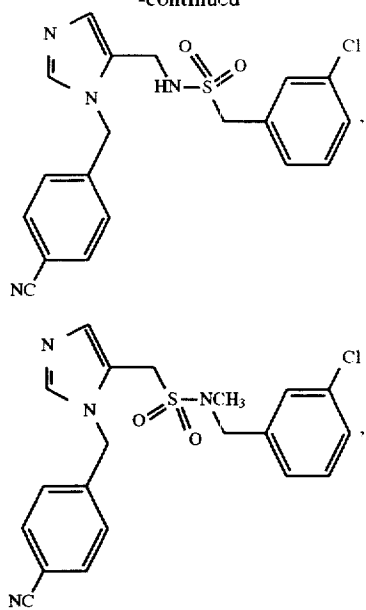
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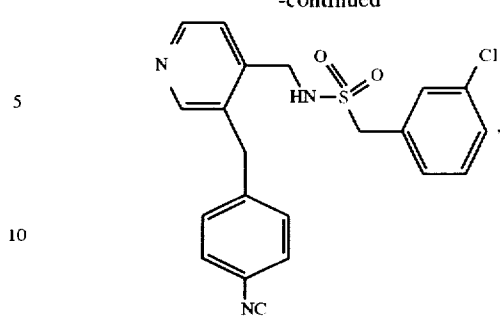
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or a pharmaceutically acceptable salt thereof.

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